CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

A CBO STUDY

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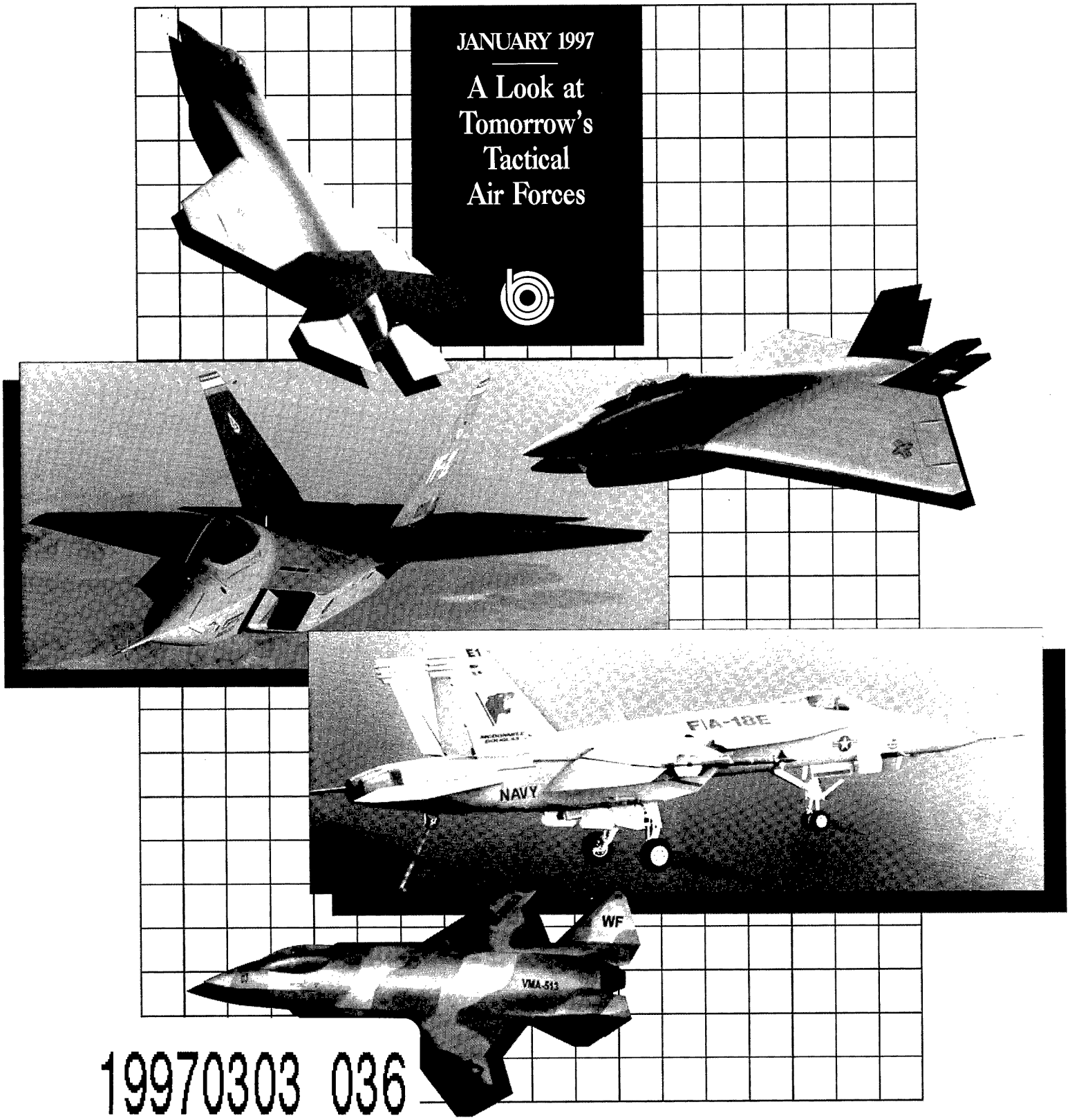
A Look at Tomorrow's Tactical Air Forces



ERRATA

A Look at Tomorrow's Tactical Air Forces

On page vi in the Table of Contents the title for the fourth option should read: Option IV: Make Proportional Cuts to All Programs and Accept Force Cuts

The second sentence under the heading **What DoD Plans for U.S. Tactical Air Forces** on page xi should read: Current plans call for the equivalent of 20 Air Force tactical fighter wings, 11 wings that operate off the Navy's large deck carriers, and four wings that include fixed-wing fighter and attack aircraft for the Marine Corps.

On page xii the last sentence in the first paragraph under the heading **The F-22** should read: If the procurement plan was to remain unchanged, F-22 purchases would continue until 2010, for a total of 438 planes.

The last sentence in the paragraph before the discussion of Option II on page xxiii should read: Air Force personnel also argue that reducing the number of stealthy planes in their fleet would increase requirements for support aircraft.

On page xxv the second-to-last sentence of the first full paragraph should read: The philosophy behind such an option is that pursuing technological challenges in the near- and midterm is more important than preserving forces.

The article referred to in the second paragraph of page 10 is the article cited in footnote 15.

The second sentence on page 15 should read: Designed during the 1950s through the 1970s, those generations include the MIG-21-MIG-27 series designed by the former Soviet Union's Mikoyan Design Bureau; F-4s and A-7s built by the United States; and the European designed Mirage 3, Mirage 5, Tornado, and F-1.

The first full sentence on page 18 should read: But potential foes may have learned lessons too, leaving little time for a U.S. build up.

The first sentence of the fourth full paragraph on page 39 should read: The price goals for the Navy and Marine Corps versions are surprisingly low, even when compared with the trend in less capable planes.

The fourth sentence in the third paragraph on page 62 should read: Moreover, the planes purchased for the Air Force will be very stealthy, particularly in the case of the F-22 if design goals are met. The last sentence of the second-to-last paragraph on that page should read: From that perspective, developing aircraft that improve the capabilities of the Navy's carrier-based air wings and the combat power of the Marine Corps' expeditionary forces is more important than designing a new plane for the Air Force's land-based wings.

The last sentence of the third full paragraph on page 65 should read: Marines also express concerns about whether helicopters—which typically do not fly over enemy forces—would be able to hit targets behind enemy lines, thereby affecting battle outcomes.

The first sentence under the heading **Cost and Capability** on page 70 should read: As suggested above, CBO intentionally structured this option to characterize the purchases that might be made if DoD spends no larger a share of the budget on fighters than it has in the past and attempts to pursue all currently envisioned development efforts.

The second sentence on page 84 should read: The Department of Defense estimates development costs at $19.7 billion or about 9 percent lower on average than CBO's estimate; DoD's cost goals for recurring flyaway costs are more than 40 percent lower on average.

The primary basis of the estimate for the cost of support and initial spares shown in Table C-5 on page 88 should read: Percentage of Recurring Flyaway Costs Based on Earlier Models.

A LOOK AT TOMORROW'S TACTICAL AIR FORCES

The Congress of the United States
Congressional Budget Office

NOTES

All years referred to in the study are fiscal years unless otherwise noted.

All dollars are expressed in 1997 budget authority unless otherwise noted.

The study uses CBO's fiscal year 1997 inflation assumptions.

Details in text and tables may not add to totals because of rounding.

Unit prices for aircraft are procurement unit costs, expressed in 1997 dollars, unless otherwise noted.

Estimates for acquisition costs total funding for the full development and production period.

Text and table discussions of the Administration's Plan are based on the fiscal year 1997 budget as amended by the Congress. The fiscal year 1998 budget submission will make changes to several of the programs discussed here, according to personnel in the Department of Defense. Details of those changes were not yet released, however, when the study went to press. Furthermore, incorporating the changes in CBO's analysis should not significantly alter the major findings.

Preface

Many of the United States' aging tactical fighter and attack aircraft will need to be replaced during the coming decades, and the military services have ambitious plans for developing and producing new-generation aircraft to modernize their fleets. Those plans carry a high price tag, however. One of the new aircraft—the Joint Strike Fighter—may become the single most costly weapon acquisition program in history, but even at the high levels of spending for tactical aircraft that are included in current plans, the services will not be able to prevent significant aging of their fleets. Many Members of Congress have begun to question whether alternatives to the Defense Department's plans need to be considered.

The Subcommittee on Military Research and Development of the House Committee on National Security directed the Congressional Budget Office (CBO) to provide this evaluation of the Administration's plans for tactical aircraft. It also analyzes several alternatives to those plans. It does not, however, attempt to choose one alternative. That approach adheres to CBO's mandate to provide objective analysis without making recommendations.

Lane Pierrot of CBO's National Security Division and Jo Ann Vines from the Budget Analysis Division prepared the report with assistance in the early stages from Shaun Black and in the later stages from Douglas J. Taylor. Shaun Black also prepared the appendix on aircraft service life.

Cindy Williams, R. William Thomas, and Michael A. Miller provided general supervision during the report's preparation. Wayne Glass, formerly of CBO, contributed greatly to the discussion of DoD's acquisition process.

The authors are grateful to Neil M. Singer, David Mosher, Frances M. Lussier, Jeffrey Holland, Eric J. Labs, Ivan R. Eland, Rachel Schmidt, Evan W. Christman, and Alexander C. Hou for their valuable assistance during the study's preparation. Thomas A. Keaney of the National Defense University and William D. O'Neil of the Center for Naval Analyses provided useful comments on earlier drafts of the study. The authors and CBO, however, bear full responsibility for the final product.

Paul L. Houts edited the manuscript. Marlies Dunson provided editorial assistance during production of the study. Cindy Cleveland produced drafts of the study, and Janice M. Johnson produced drafts of the appendix on costs. Kathryn Quattrone prepared the report for publication.

June E. O'Neill
Director

January 1997

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Summary

The United States arguably has the world's most capable inventory of fixed-wing fighter and attack aircraft. Those fighter aircraft in the Air Force, Navy, and Marine Corps represent a major part of the combat capability of the United States. Although the Department of Defense (DoD) is currently decreasing the numbers of fighter aircraft, its planned forces require inventories of about 3,500 planes.

To modernize its forces, DoD expects to acquire three new tactical fighter and attack aircraft over the next several decades—the F-22 for the Air Force, the F/A-18E/F for the Navy, and the Joint Strike Fighter (JSF)—a multipurpose plane being developed for all three services as well as for the British Royal Navy. The Department of Defense expects all three planes to be more effective than the planes they will replace.

The planes will also be extremely expensive. The Congressional Budget Office (CBO) estimates that the total cost to develop and acquire about 4,400 planes amounts to about $350 billion, even without factoring in inflation. (That estimate includes total funds for development and procurement.) Over the 1997-2001 period, DoD says it will spend about $33 billion (in 1997 dollars) on the three new aircraft.

CBO's analysis of the proposal for fighter and attack aircraft points to the following issues:

- U.S. fighter fleets now outmatch the fighter fleets of any potential adversary;
- DoD plans to purchase enough tactical aircraft to offset most of the planned retirement of older aircraft through 2020;
- DoD's plans assume that tactical aircraft will operate for long periods, and as a result U.S. tactical aircraft fleets will reach unprecedented ages;
- DoD's planned aircraft purchases for fighter fleets will be costly and will require changes in spending patterns; and
- The Joint Strike Fighter's nontraditional program structure could mask problems for DoD's plans.

The Department of Defense and the Congress may want to consider alternatives to the current plan to address problems of affordability and aging. This study examines strategies for addressing those problems.

What DoD Plans for U.S. Tactical Air Forces

The Air Force, Navy, and Marines all employ fixed-wing fighter and attack aircraft that fight enemy planes in the air and attack targets on the ground (see Chapter 1). Current plans call for the equivalent of 20 Air Force tactical fighter wings, 11 wings that operate off the Navy's large deck carriers, and four wings that includes fixed-wing fighter and attack aircraft for the Marine Corps. To fill out those force levels, DoD needs to retain about 3,500 aircraft in inventory.

By 1998, DoD will operate eight different kinds of fighter and attack aircraft. More than half of the Air Force fleet consists of F-16s (a small, relatively inexpensive, multipurpose plane) and F-15s (a larger, more capable, more expensive fighter). The remainder of the Air Force fleet has two aircraft dedicated to attacking ground targets: the rugged, tank-killing A-10 and the stealthy F-117.

The bulk of the Navy and Marine Corps inventory is made up of F/A-18s, a multipurpose plane (that is, one that performs both fighter and attack roles). F/A-18s operate both in Navy carrier-based air wings and in fighter squadrons in the Marine Corps. By 1998, only one other fighter or attack aircraft—the F-14—will operate in the Navy's carrier-based wings, since the venerable medium-range bomber, the A-6, will have been retired by then. In addition to the F/A-18, the Marine Corps will continue to operate the AV-8B Harrier, which can take off in short distances and land vertically—the so-called short takeoff vertical landing (STOVL) capability—and thus can fly from the ships that transport marines to amphibious landings.

DoD's plans for modernization call for replacing virtually all of those planes with the three types of aircraft mentioned earlier: the F-22, the F/A-18E/F, and the Joint Strike Fighter.

The F-22

The Air Force plans to buy the F-22 fighter to replace a portion of its fleet of F-15s. The first four F-22s are scheduled to be bought in 1999. Procurement quantities will increase annually until 2003, when the plane reaches a peak procurement rate of 48. If the procurement was to plan remain unchanged, F-22 purchases would continue until 2010, for a total of 438 planes.

The Air Force expects dramatically improved capability from the F-22. It will be stealthy and thus more likely to survive in dense air-defense environments. The F-22 can also attain supersonic speed without using its afterburner, which saves fuel. In addition, the F-22's design includes sophisticated software that will enable pilots to be more aware of their situation, telling them, among other things, the locations of targets and threats.

The F-22 will also be quite costly. Even if its price grows no more than it already has, the Administration estimates that on average each F-22 will cost $91 million, almost twice as much as its predecessor. DoD estimates that the costs to develop and procure the fighter alone will total $63 billion. CBO constructed an estimate for the fighter's price based on cost-estimating relationships—historical relationships between the price of planes and their weight and capability. The estimate suggests that the F-22s might cost more—perhaps $108 million per plane—for a total program cost of about $70 billion. In fact, the F-22's price may well rise above that figure. The Air Force recently announced a delay in purchasing the fighter. The new schedule for F-22 purchases is likely to be provided when the details of the 1998 budget request are released. Usually such delays entail cost increases.

The F/A-18E/F

The multipurpose F/A-18 makes up the bulk of the Navy's aircraft fleet and will continue to do so for the foreseeable future. In 1991, the Navy announced plans to develop a new E/F version of the F/A-18. The E/F version is a bigger plane with more powerful engines than the current C/D model. The Navy expects the F/A-18E/F to carry more weapons or to carry the same load about 40 percent farther. The Navy also expects the larger F/A-18E/F to be as agile in flight as the C/D model because of its higher thrust engines and larger wings. Moreover, a Navy publication suggests that F/A-18E/Fs will also be stealthier and better able to survive.

The Navy plans to buy 1,000 F/A-18E/Fs over the 1997-2015 period. It estimates that the F/A-18E/F will cost about $61 million each for a total program cost of about $67 billion. According to CBO's analysis, that estimate is in line with the costs of the earlier-model F/A-18s—after adjusting for the E/F's heavier weight.

The Joint Strike Fighter

Of the three programs, DoD's largest developmental effort is the Joint Strike Fighter—formerly called the Joint Advanced Strike Technology (JAST)—program. The JSF is also the least well defined of those programs, since it is the youngest.

According to the program office's tentative plan, about 3,000 JSFs would be bought over the 2005-2030 period. The Air Force would purchase about two-thirds of them. The Marine Corps plans to buy about 640, and the Navy would receive the remaining 300 aircraft. In addition, the British Royal Navy expects to buy about 60 of them.

The Joint Strike fighter is expected to replace a number of aircraft including the Air Force's relatively inexpensive, multipurpose F-16 aircraft, the Navy's long-range A-6 attack plane, and possibly its F-14 fighter, and the Marine Corps' AV-8B jumpjet. Despite the differences among the aircraft it is to replace and the disparity in their missions, the plane's program office would like the various JSF versions to have 80 percent in value of its components to be identical and thus interchangeable. The program office claims that such a high level of commonality together with the large number of planes to be bought will keep JSF prices down. The program will try to reduce costs in other ways as well. In fact, the JSF program's list of initial requirements includes price goals.

The Department of Defense has not yet prepared an estimate for the Congress of the total program costs for the Joint Strike Fighter. However, using DoD's stated price goals as a basis, CBO estimated that procurement funding for the JSF could total about $145 billion. Adding the program office's $20 billion estimate for development brings the total acquisition cost for the program up to $165 billion.

Yet the DoD goals underlying that estimate seem optimistic, given the expectations the services hold for improved performance. Consequently, CBO made an estimate based on the historical relationship between price and performance. If experience proves a guide in the Joint Strike Fighter program, funding needs could total as much as $219 billion—about $22 billion for development and $197 billion for procurement.

The program office for the Joint Strike Fighter received bids from all major U.S. fighter manufacturers in a recent competition to develop a concept for the plane. Three proposals—from Lockheed Martin Corporation, the Boeing Company, and a team made up of McDonnell Douglas Aerospace, Northrop Grumman Corporation, and British Aerospace Defence Limited—were submitted. On November 16, 1996, the Department of Defense announced that it had selected the Lockheed Martin and Boeing proposals.

U.S. Fighter Fleets Outmatch the Fighter Fleets of Any Potential Adversary

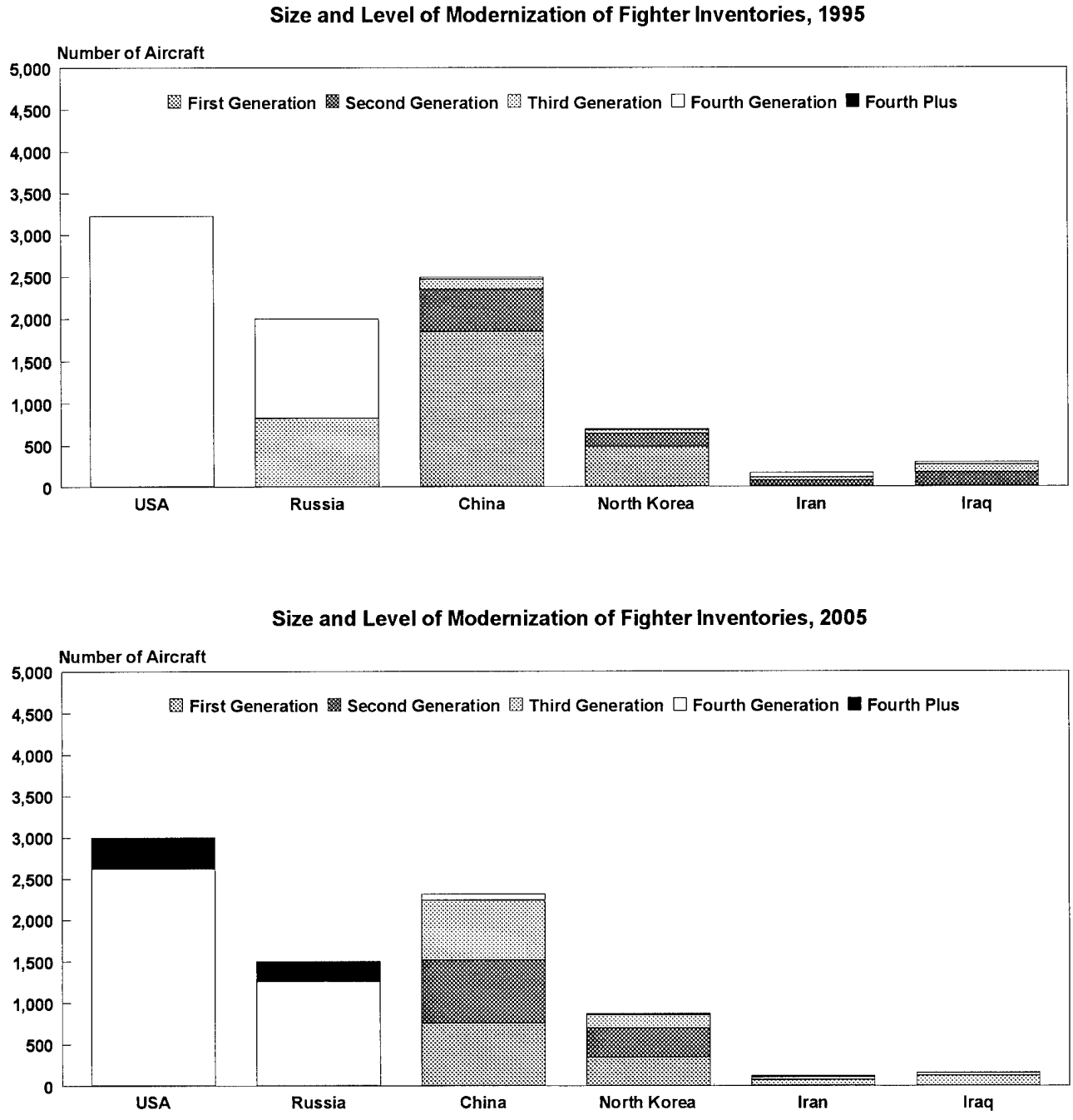
The need to modernize U.S. forces depends in part on the size and capability of the fighter fleets of potentially threatening countries (see Chapter 2). One problem with making comparisons now between U.S. forces and those of other countries is the uncertainty about which countries constitute potential threats.

Under current national security strategy, set forth in the Clinton Administration's Bottom-Up Review, DoD must keep enough forces to fight and win two major regional conflicts at nearly the same time. Those conflicts are often assumed to be in Southwest Asia—with Iraq or Iran—and on the Korean peninsula with North Korea. Some DoD analysts include in their analysis threats of both Russia and China—countries that possess considerable combat potential.

A recently released Navy analysis of threats includes estimates of each of those countries' fighter inventories for 1985, 1995, and a forecast for 2005 (see Summary Figure 1). For those estimates, the Navy excluded planes that have dedicated ground attack missions. Hence, CBO also excluded those planes from its U.S. estimate. In addition, the Navy's analysis breaks those inventories into "generations" that reflect the planes' level of technology.

According to the Navy's analysis, not one of those countries has an aircraft inventory that approaches U.S. forces in either size or modernity. By the turn of the century, the United States will have fleets of about 3,500 aircraft—including about 3,100 fighter and multirole aircraft—types similar to the planes the Navy counted for other countries. In contrast, the inventories of the three countries commonly associated with the major regional contingencies—Iran, Iraq, and North Korea—had a total of only about 1,200 planes in 1995. Total inventories in those countries will shrink to less than 1,000 planes by 2005, according to the Navy's

Summary Figure 1.
Tactical Fighters in Selected Countries



SOURCE: Congressional Budget Office using data from Office of Naval Intelligence, *Worldwide Challenges to Naval Strike Warfare* (January 1996).

NOTE: Fourth Plus equals F-117s, F-22s, F/A-18E/Fs, and JSFs.

estimate. In addition, many of those planes are old and not terribly capable.

Even though the fighter fleets of potential adversaries should be no match for U.S. fighters, defense decisionmakers may want to continue modernizing U.S. fighter fleets for other reasons—one such reason being that U.S. fighters have to contend with ground-based air defense systems as well as enemy fighters. The services regularly express concerns about unfriendly countries modernizing their air defense systems. New stealthy planes might weather improvements in air defense better than old nonstealthy ones.

Even if threats do not intensify or become more numerous, continuing to field large numbers of highly capable U.S. aircraft offers a number of advantages. The United States relies on air power to offset the capabilities of enemy ground forces, as a way to hold down U.S. casualties, and as a supporting arm for U.S. and friendly ground forces. Because of that reliance, simply offsetting enemy fighter and air-defense capabilities may not suffice. Also, aircraft—which can fly to a conflict and require less support equipment than heavy ground forces—can provide firepower earlier in a conflict than any but the lightest Army forces. If early-arriving air power is able to slow or stop attacking forces, it can make rolling back enemy forces easier.

DoD's Plans Prevent the Services from Experiencing Large Shortages Through 2020

CBO projects that DoD's planned purchases of F-22s, F/A-18E/Fs, and JSFs should make up most of the shortfall created as the three services retire their older aircraft (see Summary Figure 2). At the end of 1997, the Air Force will have almost 2,300 planes in its inventory. It needs about 2,100 planes to meet the requirements for its 20 wings, which would leave it with a small surplus of planes through the middle of the next decade. Furthermore, planned purchases of F-22s and Joint Strike Fighters will let the services avoid shortages of more than 100 aircraft until almost 2015.

The Navy and Marine Corps now have about the number of planes they need to meet a combined requirement of around 1,400 planes. The Navy will experience small shortages during most of the first decade of the 21st century.

U.S. Tactical Aircraft Fleets Will Reach Unprecedented Ages

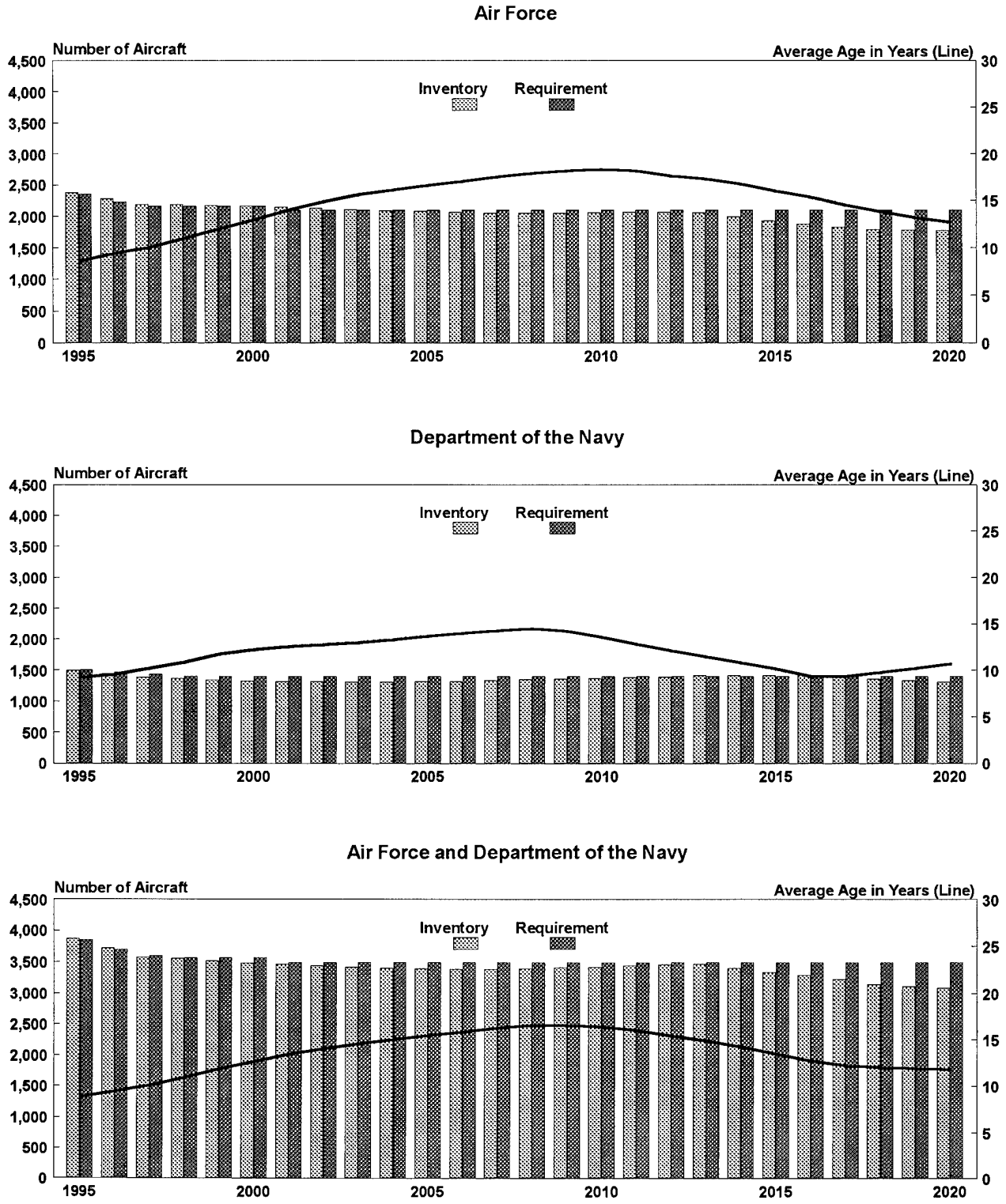
DoD's plans for aircraft purchases should permit it to support its force goals. Nonetheless, it will need to keep planes in the fleet for unusually long periods to do so. As a result, the large number of older aircraft will drive the average age of DoD's fleets to unprecedented levels (see lines on Summary Figure 2).

CBO's forecasts of future inventories depend on a number of assumptions made by the services. One key assumption is service life—an estimate that permits planners to forecast when the planes in today's fleets will retire. Both the Air Force and the Navy are expecting to retain planes longer than they have in the past. Historically, DoD has planned to retire fighter and attack aircraft when they are about 20 years old. But current plans call for retaining planes much longer. If such plans prove to be overly optimistic—as they have in several recent cases—DoD could face shortages or increased requirements for aircraft purchases.

Furthermore, since the services plan to keep aircraft longer than they expected to in the past, the overall average age of Air Force and Navy fleets will rise. In certain years, that average age will reach points that are unprecedented at least since the advent of the jet engine. Navy and Air Force fleets are now, on average, about 10 years old. They will age during much of the next decade if only because few aircraft will be purchased.

The average ages of Air Force aircraft will be higher than those in the Navy and Marine Corps, exceeding 15 years by 2003. That average age will climb to about 18 years by 2010, before it begins to decline as Joint Strike Fighters become operational. The Navy's fleet—which will receive infusions of large deliveries of

Summary Figure 2.
Fighter and Attack Inventories, Requirements, and Average Ages with Purchases of Joint Strike Fighters



SOURCE: Congressional Budget Office estimates using data from the Department of Defense.

NOTE: Aircraft retired or replaced before end of service life to fit requirements.

F/A-18E/Fs in the early years of the next decade—will remain relatively younger, reaching an average age of about 14 years around 2005. The average age will increase slightly until 2008 and then begin declining, when the Navy also receives deliveries of the Joint Strike Fighter.

The Department of Defense uses the average age of its aircraft fleet as a measure of modernization and a proxy for obsolescence of large blocks of the fleet. In the past, DoD officials have also argued that aging fleets will be less capable in combat, since enemy fighter fleets and air defenses will modernize. The services also express concern that older fleets will be more difficult to operate and more expensive to maintain.

Those trends in aging may be of less concern than they were during the Cold War. But they do indicate that future Administrations will have far less flexibility in responding to structural fatigue problems such as those recently encountered with the F-16A/B. If old planes require modifications, they could add substantially to overall funding requirements.

DoD's Plans Will Be Costly and Difficult to Afford Without Changing Spending Patterns

If problems develop with the aging fleet, adding to funding for fighter planes could pose serious difficulties. The Administration's plans to modernize are already costly. CBO estimated future funding required to purchase the three new planes in the Administration's current plan. It then compared that amount with the funding that might be available if DoD allocated the same share of its future budget to purchasing fighter and attack aircraft as it has in the past. For that base case, CBO's projections of fighter costs are based on DoD's estimates for fighter prices rather than the higher estimates CBO developed based on cost-estimating relationships.

On average, the Air Force and the Navy spent about 4.6 percent and 3.6 percent, respectively, of their annual budgets on purchasing fighter aircraft over the 1974-1997 period. CBO applied those percentages to the Administration's plans for service budgets in 2001—the last year for which plans were available. According to that estimate, the services might have a total of about $6.3 billion to spend for fighter aircraft each year if they follow past patterns in spending and if their budgets remain level after 2001 (see Summary Figure 3).

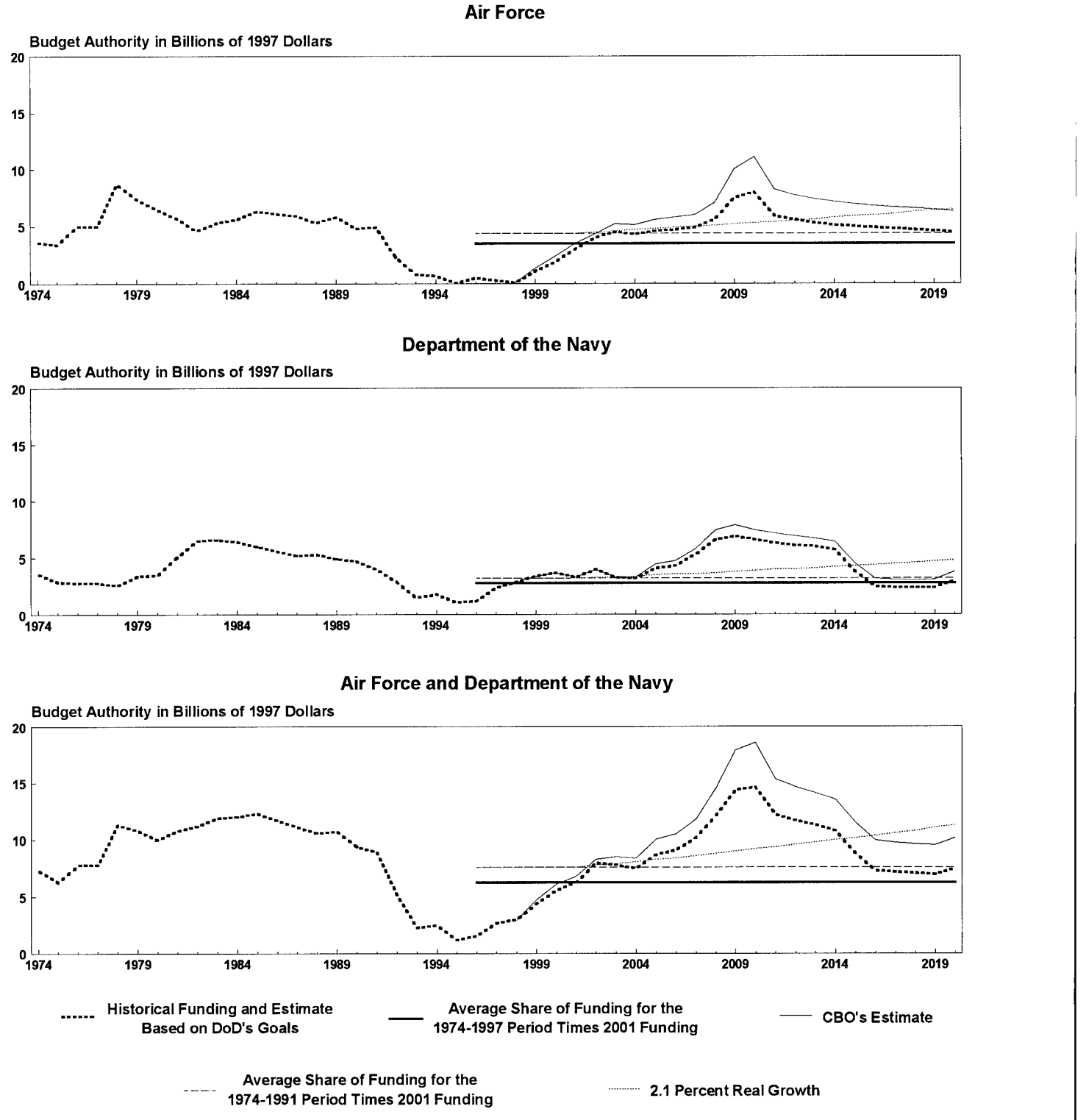
However, CBO projects that spending to purchase the fighter and attack aircraft in DoD's plans will average $9.6 billion annually over the 2002-2020 period—that is, more than $3 billion more than might be available if the services' budgets remain constant and fighters received the same share as they did previously. If DoD's estimates of procurement costs prove too optimistic, as CBO's analysis indicates, the gap would be even greater.

Purchasing the Planes in DoD's Plans Will Require Large Changes in Spending

The United States could, of course, change its spending patterns in ways that would make more money available to procure future fighter aircraft. Unfortunately, fairly sizable changes would be needed. DoD argues that it will allocate a larger share of its budget to fighters during the next decade than it has historically. If DoD's prediction proves to be accurate and increased percentages of service budgets are in fact given to funding tactical fighter aircraft, then current plans might be affordable. But the increases in the service budgets would have to be substantial.

Over the 1974-1997 period, the Navy devoted an average of about 3.6 percent of its budget to purchasing fighter and attack aircraft. It would need to increase that share for the 18-year period from 2002 to 2020 to 5.7 percent—or almost a 60 percent increase—even if prices do not rise above the Administration's plans. If prices do rise to the levels in CBO's estimates, the Navy will have to increase funding for fighter aircraft purchases to more than double its previous shares. The Air Force would need to enlarge the share it devotes to buying fighters as well.

Summary Figure 3.
Historical and Projected Funding for Fighter and Attack Aircraft (By fiscal year)



SOURCE: Congressional Budget Office.

Consider another possible assumption—namely, that total defense budgets would increase. In the above discussion, the Congressional Budget Office assumed that DoD budgets would receive no real increases in funding beyond 2001. But that assumption presumes a unique funding pattern for DoD: at least since World War II, DoD budgets have never gone through such a long period with no growth in funding. Therefore, assuming that future budgets would indeed escalate may be reasonable. But if in fact fighter funding received its average share for the 1974-1997 period, service funding would need to grow by more than 2 percent a year in real terms over the 2002-2020 period to purchase the planes in the current plans, even if aircraft prices did not exceed the department's current goals.

Other Changes in Spending Patterns Could Make Planned Purchases More Difficult to Afford

Other assumptions about future spending would darken the outlook for affordability. For one thing, DoD budgets could shrink. Suppose that in the next decade the Congress and future Administrations make tax cuts while reaching and retaining a balanced budget. In that case, the defense budget could undergo real cuts. Indeed, the Congress's roadmap for federal spending and revenues into the next century assumes real declines in defense funding authority through 2002.

Other portions of the budget could also put pressure on future defense budgets. Two particularly critical programs are Medicare and Social Security. Unless they are changed substantially, the aging baby-boom generation will require an ever-larger share of the budget during the same period that requirements to purchase fighter aircraft are growing. Perhaps for all those reasons, at least one industry association—the Electronics Industry Association—accords high probability to forecasts of real declines in DoD's funding around the turn of the century and beyond.

In addition, purchases of fighter planes could lose out, within the procurement accounts, to other weapons. For example, the Navy expects to purchase about twice as many ships on average during the 2002-2020 period as during the 1997-2001 period. Furthermore, the Army plans to modernize its helicopter fleet extensively. Also, any increases to fund long-range bombers or airlift aircraft could come out of funds for fighter planes.

Although some mission areas—such as antisubmarine warfare—have been deemphasized at the end of the Cold War, other areas, such as mobility, have escalated in importance. National and theater-level missile defenses could be strong contenders for defense funds. Moreover, the end of the procurement holiday that has increased pressure for larger fighter purchases may push up purchases of other types of weapons.

The Department of Defense may also find that the planes it purchases carry a higher price tag. DoD's price goals—particularly for the Joint Strike Fighter—assume that the department will be able to break away from historical relationships between cost and capability and aircraft weight. To cite one example, DoD's estimate of the Joint Strike Fighter assumes that it will garner a number of improvements in performance, including stealth, with little or no cost penalty. Since the Administration argues that it will place considerable emphasis on keeping prices down in its design programs, CBO shows an estimate based on DoD's goals. Yet a careful look at history shows that such goals are highly optimistic.

CBO also estimated prices for those planes using cost-estimating relationships that link aircraft price to aircraft size and performance. According to CBO's analysis, only one plane—the F/A-18E/F—has costs that reflect historical cost-estimating relationships. The F-22's unit procurement price of $91 million could rise to about $108 million if cost-estimating relationships prove to be better price predictors than the estimating methods DoD used. Taken together, CBO's higher estimates indicate that DoD might need to spend an average of $11.9 billion annually—$2.3 billion more than the DoD estimate—on fighter and attack aircraft over the 2002-2020 period. If so, DoD would have to alter its spending patterns dramatically to pay such sums.

The Joint Strike Fighter Is the Centerpiece of DoD's Fighter/Attack Plans and a Departure from Past Patterns

The success of DoD's plans for tactical fighter procurement depends in great measure on DoD's ability to produce a Joint Strike Fighter that departs from past development and production patterns for fighter aircraft (see Chapter 4). One of the greatest departures from past practices is the number of missions that the JSF family of aircraft is expected to undertake. The plane is supposed to perform virtually every mission that fighter aircraft perform in the force structure today and, moreover, to do so with a family of planes that have as many as 80 percent common parts (by value).

Joint Strike Fighters are to be fielded in Air Force, Navy, and Marine Corps inventories, an employment pattern not seen since F-4 fighters made up a large portion of service inventories. Partly as a result of that high level of cross-service operation, commonality, and the use of commercial practices, JSF's are expected to break a spiraling of prices for fighter aircraft that has been going on for at least 40 years.

The question is whether the Joint Strike Fighter will be able to meet those ambitious goals. The large array of missions planned for the fighter gives some aircraft designers pause. They perceive that a number of the goals set for the JSF might be incompatible. For example, the price of the JSF will need to be kept relatively low to meet the Air Force's need to purchase planes in quantity. But the Navy's desire for a highly stealthy aircraft that can operate over fairly long ranges could drive up the price. Also, planes that can operate off of the amphibious ships that transport Marines to war typically pay for that capability by being less capable in other areas, such as carrying smaller loads shorter distances. Some analysts argue, however, that any diminished range would be offset by basing the planes near the battle.

Such conflicts may suggest that the services will have to make compromises if the JSF program is to retain its joint service characteristics. The services may be willing to accept operational trade-offs. But many DoD programs start out assuming a high level of joint participation among the services that dissipates or never even materializes. In fact, some service leaders have already voiced concerns about the requirements of other services. For example, both Air Force and Marine Corps leaders have questioned whether the Navy's range and payload requirements will drive up the JSF's price.

Some critics also worry that the JSF is the most complex development program to fall under DoD's new guidelines for acquisition. Those new rules permit programs to skip many traditional DoD reviews. Such reviews take time and often add to the cost and complexity of a program, but they also may lessen the likelihood that DoD spends too much time (and money) on a beleaguered program.

The program's expectation of holding down the price of the Joint Strike Fighter would represent a significant break with past experience. If the plane's costs reflect previous trends in prices, total procurement costs could be about 36 percent higher than current estimates—climbing to about $197 billion. According to CBO's higher estimate, DoD may need about $11.9 billion per year—or if past spending programs are a guide, almost 90 percent more than the $6.3 billion in annual funding associated with past shares.

Other Options Might Be Considered For Modernizing Tactical Aircraft

Since the Administration's plan may produce funding shortfalls, the Congress and the Department of Defense may wish to consider alternatives. CBO evaluated four alternative strategies that might be pursued in the future if less money is available for purchasing tactical fighters than current plans require (see Chapter 5). Sketched broadly, the strategies are:

- Set priorities for development and develop airplanes for the highest priority missions;
- Build on existing development programs by creating cross-service versions;

- Purchase aircraft now in production; and
- Make proportional cuts to all programs and accept cuts in forces.

Option I: Set Priorities for Development

The Congress might wish to consider an alternative that sets priorities for modernization. Some critics of the size of DoD's air forces have argued that considerable duplication of effort exists in tactical aviation. DoD could place priorities on its force requirements and consequently modernize and retain only the highest-priority forces. CBO's Options IA and IB illustrate two approaches to pursuing that strategy.

Option IA: Set Priorities for Tactical Aircraft Development—Emphasize Air Force Missions. Because Air Force Joint Strike Fighters are to be purchased in the largest quantities, DoD could choose to modernize the Air Force fleet while eliminating requirements for a stealthy Navy strike fighter and a Marine Corps advanced short takeoff vertical landing (ASTOVL) version. (For types and quantities of

Summary Table 1.
Types and Quantities of Aircraft Purchased Under Alternatives for the 1997-2020 Period

Aircraft	Administration's Plan	Options					
		IA	IB	IIA	IIB	IIIA and IIIB	IV
				Air Force			
F-16	6	6	894	6	6	768	6
F-15E	6	6	492	6	6	214	6
F-22	438	438	0	438	438	240	240
F/A-18E/F	0	0	0	1,202	1,202	0	0
JSF(AF)	1,320	1,320	0	0	0	550	556
Subtotal	1,770	1,770	1,386	1,652	1,652	1,772	808
				Navy			
F/A-18C/D	6	6	6	6	6	1,066	6
F/A-18E/F	1,000	1,000	1,000	1,300[a]	1,300[a]	0	650
F-117N	0	0	0	0	204	0	0
F-22N	0	0	0	180	0	0	0
JSF(N)	180	0	b	0	0	96	92
Subtotal	1,186	1,006	1,006	1,486	1,510	1,162	748
				Marine Corps			
New AV-8B	0	0	0	0	0	60	0
Comanche	0	0	0	258	258	0	0
JSF (ASTOVL)	480	0	660	0	0	228	146
Subtotal	480	0	660	258	258	288	146
Total	3,436	2,776	3,052	3,396	3,420	3,222	1,702

SOURCE: Congressional Budget Office.

NOTE: JSF = Joint Strike Fighter; ASTOVL = advanced short takeoff vertical landing.

a. Includes purchases for Marine Corps squadrons.

b. CBO assumed advanced short takeoff vertical landing versions of the Joint Strike Fighter are purchased for the Navy's carrier air wings. Those planes are included in Marine Corps purchases.

planes purchased under the Administration's plan and alternatives during the 1997-2020 period, see Summary Table 1.) Under this alternative, CBO assumes that Air Force and Navy fighters would provide air support for Marine Corps ground forces and that no planes would be bought for Marine Corps squadrons providing dedicated air support.

The option also assumes that DoD would continue to purchase F/A-18E/Fs and F-22s in the quantities currently assumed under Administration plans. Since the option purchases about the same number of planes for the missions it retains, it produces fleets about the same age as the Administration's plan. The option might offer somewhat less risk of design failure, since it eliminates the more challenging aspects of the JSF program. Moreover, it would be somewhat more affordable than current plans: its procurement would cost about $9.4 billion each year on average over the 2002-2020 period compared with the $11.9 billion for DoD's plans (see Summary Table 2).

Even so, the option is still pricey—requiring roughly 50 percent more funding than the amount associated with historical shares. Option IA would also leave the Navy without a highly stealthy plane at least through 2020 and probably much longer. Not least, DoD has rejected options that, like this one, would have eliminated dedicated Marine Corps aircraft because it feared that the other services would not do an adequate job of supporting Marine ground forces.

Option IB: Set Priorities for Tactical Aircraft Development—Emphasize Navy and Marine Corps Missions. Some defense experts have argued that the air forces of the Navy and Marine Corps should receive highest priority in the post-Cold War environment. Naval forces would of course be available even if conflicts arose in locations where the United States lacks access to regional air bases and therefore to the infrastructure needed to field ground-based U.S. air forces successfully. Some supporters of naval forces believe that the increased uncertainty about the location of future conflicts suggests that they are more likely to occur in such locations. Such a world view might imply that it is more important to develop aircraft that improve the capabilities of the Navy's carrier-based air wings and the Marine Corps squadrons that provide a substantial portion of the combat power of the Marine Corps' expeditionary forces.

Summary Table 2.
Average Annual Procurement Funding for Administration's Plan and Alternatives (In billions of 1997 dollars)

Alternative	Period 1997-2001	Period 2002-2020
Administration's Plan (CBO's Estimate)	4.7	11.9
Option IA: Set Priorities for Development (Emphasize Air Force Missions)	4.7	9.4
Option IB: Set Priorities for Development (Emphasize Naval Missions)	5.6	7.4
Option IIA: Build on Existing Development Efforts (with F-22N)	4.7	9.3
Option IIB: Build on Existing Development Efforts (with A/F-117X)	4.7	9.2
Option IIIA: Emphasize Current Generation Aircraft	5.3	7.9
Option IIIB: Emphasize Current Generation Aircraft with Modifications	4.9	8.3
Option IV: Make Proportional Cuts	4.7	6.3

SOURCE: Congressional Budget Office.

NOTE: Prices based on cost-estimating relationships.

Option IB assumes that DoD chooses to develop planes to modernize those naval forces while deferring the modernization of land-based Air Force units. Specifically, the alternative assumes a variation of the Joint Strike Fighter is developed for the Navy and Marine Corps. The option would develop only the short take-off vertical landing version of the JSF and purchase it for both carrier air wings and Marine Corps squadrons (original plans for the ASTOVL concept included fielding the plane on both the large-deck Navy aircraft carrier and the small-deck amphibious ships). In keeping with the theme of emphasizing naval forces, the alternative also continues the interim development and purchase of the F/A-18E/F.

Since the alternative deemphasizes land-based fighter and attack missions, it cancels the JSF version for the Air Force, though it hedges against uncertainty by purchasing 894 F-16Cs. Those purchases should provide enough planes to avoid cuts in Air Force fighter and attack forces.

Option IB also cancels development of the F-22 program. Some analysts feel that the modest capabilities of the fighters of potential enemies provide insufficient justification for developing a plane with the F-22's price and performance. They also believe that DoD's fighter and attack dollars would be better spent on planes that focus more on ground attack. In keeping with that point of view, this alternative continues purchases of the F-15E, a variation of the Air Force fighter that emphasizes the interdiction mission, buying 492 planes.

Because Option IB purchases less capable, less expensive planes on average, it would be less expensive than the Administration's plan. In fact, it would have an average annual procurement cost of about $7.4 billion over the 2002-2020 period, about $4.5 billion less than the Administration's plan. Thus, it should be easier to afford than that plan. The option should also entail less risk in development than the Administration's plan, since it would build fewer new planes.

Not that Option IB is without flaws. It is still expensive and might be difficult to afford. The Air Force argues that canceling the F-22 would increase combat losses in future conflicts and that canceling the program at this late stage entails wasting substantial funds. Canceling the F-22 could also cause a delay in the Joint Strike Fighter program, the reason being that the program depends on successful development of the F-22's engine and some F-22 avionics. Air Force personnel also argue that reducing the number of stealthy planes in the their fleet would increase requirements for support aircraft.

Option II: Build on Existing Development Efforts

CBO considered another alternative that would restructure planned development. Option II assumes that DoD would design versions of planes that are farther along in the development process than the Joint Strike Fighter and would purchase more of them. Such a strategy would be similar to the Navy's approach, when it decided to modify the F/A-18 and use it for a larger portion of its carrier-based aviation fleet instead of building a new plane. The option would be almost as costly as Option IA. Yet it would pose less risk of prices escalating and would, moreover, permit DoD to field a highly capable fleet.

Specifically, under one version of Option II, CBO assumes that DoD would design and purchase a version of the Air Force's F-22 for the Navy, buying 180 of the planes through 2020, a number equal to the Navy's planned JSF purchases for the period. (CBO also considered a version of this option that would purchase a naval version of the Air Force's stealthy F-117.) Under Option II, DoD is also assumed to purchase F/A-18E/Fs both for the Navy as the Administration plans, for Marine Corps fighter squadrons, and also to fill out the Air Force's requirement for the Joint Strike Fighter. A seaborne version of the stealthy Comanche attack helicopter that the Army is developing is assumed to meet close air-support requirements for the Marine Corps.

Option II would entail less risk of design failure than the Administration's plan, since developing those versions should be less challenging than developing the totally new Joint Strike Fighter. Since it purchases a stealthy plane for the Navy, buys dedicated air support for the Marine Corps, and purchases a plane that meets some of the Air Force requirements for the JSF, Option II may provide improvements in capability over DoD's current plans.

However, because Option II purchases the same number of planes on roughly the same schedule as the Administration's plan, it would cause similar problems of aging fleets. Further, its price—an average of $9.2 billion to $9.3 billion per year over the 2002-2020 period—is almost as high as that of Option IA. (The price depends on whether CBO assumes that future administrations purchase the F-22N—the higher end of the range—or the A/F-117X—the lower.) Although this option is $2.6 billion to $2.7 billion less costly than the Administration's plan over the same period, it greatly exceeds the funding for previous shares of the budget for fighter aircraft.

Option III: Purchase Aircraft That Are Now in Production

One way to keep force size up and avoid substantial fleet aging, while holding funding down, would be to continue purchasing aircraft that are already in production—and cancel or scale back the development programs. For example, the fiscal year 1997 authorization conference bill recommends continued purchases of F-15s, F-16s, and F/A-18C/Ds. Hence, CBO also considered Option III, which would continue such purchases.

In fact, this option purchases 1,066 F/A-18C/D aircraft—60 more than the total Navy F/A-18 plan. It also buys 768 F-16s and 214 F-15Es for Air Force fleets. CBO evaluated two variations of Option III. One would purchase current model F-16C/Ds. The other variation would pursue the F-16 multistaged improvement program (MSIP) that would produce an upgraded F-16. The F-16 MSIP has improved avionics and carries a wider range of weapons. Option III would also buy 60 new AV-8Bs to add to the Marine Corps's close air-support stocks in addition to the remanufactured planes the Administration plans to buy.

To pay for those additional purchases of aircraft, Option III cancels the F/A-18E/F program. It also delays the F-22 and purchases only 240 planes—198 less than the currently planned quantities. Moreover, the option defers the Joint Strike Fighter program by seven years, though it provides modest interim development funding to explore concepts for new fighters. Beginning in 2003, when CBO assumes DoD will start developing the Joint Strike Fighter in earnest, the alternative assumes that DoD would follow the same research, development, test, and evaluation funding and procurement patterns in today's plan. As a result of the delay, under Option III, purchases of the Joint Strike Fighter would begin in 2012, seven years later than the JSF Program Office now plans.

Keeping the current generation of planes in production and deferring modernization may be acceptable to those policymakers who do not expect extensive modernization on the part of potential adversaries for several decades. The additional aircraft purchased under Option III's assumptions would slow fleet aging in the near term compared with the Administration's plan. The aircraft would also be sufficient to eliminate the modest shortages the Department of the Navy experiences in the near term under current plans. The delays in development assumed under the option should also reduce design risks for the F-22 and JSF programs, though the designs—particularly for the JSF—would still be challenging. In addition, the forces purchased under this alternative would represent considerable improvements in capability over today's fleets, though such improvement would be more limited than that of the other alternatives considered.

Option III might also have a better chance of being affordable. By definition, it costs as much as the Administration's plan during the 1997-2001 period. But it yields much lower costs during the 2002-2020 period: annual requirements for funding procurement average from $7.9 billion to $8.3 billion depending on which F-16 model is purchased. Those sums represent savings of $3.6 billion to $4.0 billion compared with DoD's current plan. As a result of shifting the costs for developing the JSF out to the 2002-2020 period, some of those savings would be offset by modest increases in funding for development during that period (about $0.2 billion higher than the Administration's plan for both versions). Although those costs are less than the Administration's plan, they remain about 25 percent to 30 percent higher than the funds for previous shares of funding for fighter aircraft.

Option III will also draw criticism from the services. The Air Force is already concerned about cuts to F-22 purchases. The Navy would raise concerns about losing the added range and stealth associated with the F/A-18E/F program. Not least, the Marine Corps would find the 60 added AV-8B insufficient compensa-

tion for the JSF delay. But if affordability is a concern, that sort of strategy might represent a way to lower costs while keeping forces at levels close to those currently planned.

Option IV: Make Proportional Cuts to All Programs and Accept Force Cuts

CBO also considered an option that would focus on modernization at the expense of force structure. The option was constructed to bring procurement spending during the 2002-2020 period for each service's fighter purchases close to the levels associated with shares that the services have given it in the past. Moreover, the option would continue to develop all currently planned modernization programs and allocate cuts proportionately. The philosophy behind such an option is that pursuing technological challanges in the near- and mid-term is more important than preserving forces. It also reflects a budget process that shares the pain of budget cuts evenly among participants, rather than picking winners and losers.

By definition, Option IV assumes DoD would spend $6.3 billion annually on procurement over the 2002-2020 period—an amount equal to that associated with previous shares. The option cuts purchases proportionally to meet funding shares. Also, by definition, funding to develop fighter aircraft equals the amount in the Administration's plan. The option cuts purchases proportionally to meet funding shares.

Total aircraft purchases under those rules would be cut from the 3,436 planes to be bought during the 1997-2020 period under current plans to 1,702 planes. CBO assumes that DoD would size its investment in production tooling to lower aircraft production rates if it decided in advance that it would produce smaller numbers of planes, thereby avoiding many inefficiencies from unanticipated rate reductions. Nonetheless, a small penalty in aircraft prices arises. As a result, the cut in funding is not proportionate to the cut in purchases. If producers build fewer planes, they do not learn as much or become as efficient.

In the past, DoD has paid significant amounts because it equipped facilities that could handle high rates that were realized for short periods, if at all. Hence, even though Option IV may be generous in its assumptions about the efficiency of DoD's choices in equipping production facilities, it produces an unusually small, very old force. By 2015, DoD's fighter and attack inventories would be short about 650 planes—the Navy would be short about 300 planes and the Air Force would be short about 350 aircraft. By 2020, after five more years during which large blocks of aircraft delivered in the 1980s retire without replacement, shortages will rise to almost 1,450—or more specifically around 935 in the Air Force and about 515 in the Navy. As a result, Air Force structure might need to be cut almost in half and Navy force structure could be considerably reduced.

Aircraft inventories under Option IV would also be old—since so few new planes would be purchased. By 2020, Air Force inventories would average 19 years of age. In other words, the Air Force fleet would be even older than it would be under the already unprecedented ages of the Administration's plan. Navy inventories would average 14 years of age in 2020, compared with 11 years under the Administration's plan.

Chapter One

Introduction

How strong is U.S. air power? One way to answer that question is to provide an inventory of sorts—to look at the number of forces and the nature of U.S. combat air power. The United States employs a variety of weapons that provide combat air power, including strategic bombers, cruise missiles launched from ships, ground-launched Army missiles, and Army and Marine Corps attack helicopters. But fixed-wing fighter and attack aircraft provide the bulk of U.S. combat air power. The U.S. Air Force fields the equivalent of 20 fighter wings at bases in the United States and abroad. The Navy's large deck aircraft carriers accommodate 11 wings, and the Marine Corps has four wings to provide fighter cover and air support to its ground forces.

Overall, the Department of Defense (DoD) now has about 3,700 fighter and attack aircraft in its inventory to support its forces. Those planes will have to be replaced, however, over the next several decades as they reach the end of their service lives. The Administration hopes to meet that requirement for new tactical aircraft with three new planes: the F-22 air superiority fighter, an improved version of the Navy's F/A-18 fighter and ground attack aircraft, and the Joint Strike Fighter (JSF).

Yet, even under the most optimistic assumptions about costs, DoD's fighter programs will be expensive: Based on DoD's price goals, they will collectively cost almost $300 billion. Whether the Administration will be able to meet its ambitious goals for performance and cost-cutting is a big question. The Congressional Budget Office (CBO) estimates that the costs for the planes could total about $350 billion. Moreover, critics have expressed doubts about plans for all three planes. They argue, for example, that the improvements in performance the F-22 is expected to deliver are too costly and not needed and that planned improvements in performance of the F/A-18E/F are optimistic, unneeded even if realized, and, again, far too costly, particularly during a period when budgets are tight.

Still, for all the controversy about the F-22 and the F/A-18E/F, concerns about the Joint Strike Fighter may be the most troubling, since it makes up about two-thirds of total planned procurement. Critics have doubts about the ability of the JSF program to deliver a family of aircraft that can meet the distinctly different requirements for each of the services—namely, an inexpensive, multirole fighter for the Air Force; a very stealthy, longer-range, carrier-based, ground-attack plane for the Navy; and a multipurpose fighter for the Marine Corps that will be able to take off from the short deck of an amphibious ship and land vertically.[1] (The Navy operates 11 amphibious ships that can transport Marines to battle and that are the size of the aircraft carriers of many countries.)

Whether DoD will be able to keep within its budget for each of the three planes is also open to question. Even if the cost of the planes remains within budget, planned funding for DoD's military hardware is so high that even the Chairman of the Joint Chiefs of Staff suggested that it was unaffordable.[2] Moreover, Admiral William Owens, just before retiring as Vice Chairman of the Joint Chiefs of Staff, toted up the funding for

1. Statement of Robert F. Hale, former Assistant Director, National Security Division, Congressional Budget Office, before the Defense Subcommittee of the Senate Committee on Appropriations, May 12, 1993.

2. Memorandum from General John M. Shalikashvili, Chairman of the Joint Chiefs of Staff, to William J. Perry, Secretary of Defense, October 17, 1995.

those three programs and testified that it amounts to more than 40 percent of the funding for the Pentagon's 20 most expensive programs.[3] Although the percentage the Admiral used may be accurate, the calculation may be a little unfair. The estimate is based on dividing future tactical air funding by the total of the 20 most expensive systems included in DoD's Selected Acquisition Report, a report to the Congress of major acquisition efforts. The share of total investment for tactical fighters will be lower, since their funding is disproportionately represented in major acquisition funding. Nonetheless, Admiral Owens' main point—that the Department of Defense plans to focus substantial resources on tactical fighter and attack aircraft in the future—is still accurate.

Missions of Combat Aircraft

Why, one might ask, with the Cold War over, is DoD planning to purchase fighter aircraft that could cost some $350 billion? To answer that question, one needs to know more about the functions of such aircraft. Stated in the sparest terms, fighter and attack aircraft perform three major missions: air superiority, interdiction, and close air support, as well as other, more minor ones. Those missions, however, are far more difficult, extensive, and complex to achieve than they might appear to be at first glance.

Air Superiority and Counter-Air Missions

The Department of Defense defines the mission for air superiority (also known as counter air) as protecting the United States, its forces, and its allies from air attack, attacking and suppressing enemy air forces and air defenses, and gaining and maintaining control of the air. Early in a war, air forces are likely to place their highest priority on air superiority.[4] Fighter/interceptor aircraft have the primary mission of using guns and air-to-air missiles to attack enemy planes and missiles.

The Air Force's current top-of-the-line fighter/interceptor is the F-15 A-D and the Navy's is the F-14A, B, and D (see Table 1 for a description of planes currently in the force). F-16s and F/A-18s in the Air Force and Navy, respectively, are multirole aircraft. They are fighter/interceptors but can also attack enemy aircraft, though to control costs, they have less capability than single mission fighter/interceptors. The other portion of the air superiority mission—suppressing enemy air forces by bombing air bases and attacking enemy ground-based air defenses—requires planes designed for air-to-ground or "attack" missions.

Interdiction and Close Air Support

Interdiction and close air support are the two major attack missions of tactical air forces. The Navy refers to such missions that involve attacking targets on the ground as strike warfare.

In the interdiction mission, aircraft attack targets to divert or destroy an enemy's military potential. The so-called "battlefield interdiction mission" involves attacking targets threatening friendly troops. Planes performing "deep interdiction missions" attack targets well behind enemy lines. The main difference between deep interdiction and battlefield air interdiction missions is that the first may require planes to attack targets at greater ranges whereas the second requires more coordination with the ground component commander during planning. The Air Force employs the F-15E, F-117, and the A-10 in interdiction missions. Both the Air Force's F-16 and the Navy's F/A-18 also perform interdiction missions, as does the Marine Corps' AV-8B.

Aircraft perform deep interdiction missions against a number of static targets such as communication networks, leadership headquarters, bridges, and transportation infrastructure. When such missions involve attacks against air-defense networks and airfields, however, medium-range attack aircraft are considered to be performing the air-superiority mission. Attacks against moving targets such as second-echelon enemy ground forces are also included in the interdiction mission.

3. John Robinson, "UAVs [unmanned aerial vehicles] could replace several manned aircraft, Owens says," *Defense Daily*, February 29, 1996.

4. William J. Perry, Secretary of Defense, *Annual Report to the President and the Congress* (March 1996), p. 168. Some people would argue that this description by the Administration best articulates how the U.S. Air Force would plan an air campaign and that, in reality, planes are just as likely to be used to attack other targets early in a war.

Close air support—the third attack or strike mission —involves engaging enemy ground forces that are an immediate threat to or are already engaged in combat with friendly forces. The difference between battlefield air interdiction and close air support depends on the distance between friendly and enemy forces. Some analysts argue that very little true close air support—attacks on targets close to friendly lines—will actually occur in future battles. Pilots may have to fly at relatively low levels and slow speeds to be certain they are not attacking friendly forces when battle lines blur. But new shoulder-fired air defense missiles may put at risk even the most heavily armored planes that adopt such flight patterns. Nonetheless, the Air Force's A-10 and F-16 are often billed as a close air-support aircraft. The Marine Corps also expects the AV-8B and the F/A-18 to provide close air support. All of those aircraft have less armor than the A-10.

Other Missions

The military services used to employ specialized aircraft to suppress enemy air defenses. The Air Force's F-4G Wild Weasel aircraft, for example, were dedicated to attacking air defense sites with High-Speed Anti-Radar Missiles (HARM). The modern trend, however, is to use a multirole aircraft such as the F-16 or F/A-18 for that role. The specialized equipment necessary to locate the target is stored in a pod that can be

Table 1.
Current Tactical Fighter and Attack Aircraft

Aircraft	Popular Name	When It Entered the Force In Bulk	Primary Missions[a]	Procurement		RDT&E (Billions of 1997 dollars)
				Quantity	Unit Cost (Millions of 1997 dollars)	
			Air Force			
A-10	Warthog	Late 1970s	Close air support	727	11	1.4
F-15A-D	Eagle	Mid-1970s	Air superiority	865	46	6.7
F-15E	Strike Eagle	Late 1980s	Interdiction	209	55	1.9
F-16A-D	Falcon	Early 1980s	Multirole	2,201	23	4.2
F-117	Nighthawk	Mid-1980s	Interdiction	59[b]	110	n.a.
			Department of the Navy			
A-6E	Intruder	Mid-1970s[c]	Interdiction or strike	205	39	0.1
AV-8B	Harrier	Mid-1980s[d]	Close air support	279	34	2.5
F-14	Tomcat	Early 1970s	Air superiority	583	55	5.9
F/A-18A-D	Hornet	Early 1980s	Multirole	1,015	44	6.0

SOURCE: Congressional Budget Office.

NOTE: RDT&E = research, development, test, and evaluation.

a. CBO uses the term "primary missions" to describe those that the planes are most likely to perform or for which they were designed. Aircraft may perform other missions.

b. Only 59 production model F-117s were bought in total. (Five prototypes were also built, some of which were modified to production configurations.)

c. The original A-6 models were developed in the 1950s and fielded in the 1960s.

d. The United Kingdom developed the original AV-8 models in the 1960s, and they were purchased for the Marine Corps in the early 1970s.

affixed to the aircraft. A similar approach is being taken with reconnaissance and surveillance missions, in which a reconnaissance pod on an F-16 or F/A-18 can replace a dedicated aircraft such as the RF-4.

Other Systems That Perform the Strike and Counter-Air Missions

The Department of Defense employs a number of other weapons that attack targets on the ground and defend U.S. troops from attack by enemy aircraft and missiles.[5] For instance, the Air Force maintains about 125 strategic bombers—with longer ranges and larger payloads than the fighter and attack aircraft—that are now generally assumed to be available for attacking targets in a regional conflict. (During the Cold War, many of those planes were withheld for possible strategic nuclear missions). In addition, the Navy can fire cruise missiles from surface ships and submarines, which can attack targets at ranges of about 1,000 nautical miles. Moreover, the ground forces of the Army and Marine Corps also have large numbers of surface-to-surface missiles, tanks, and attack helicopters that would be available in a sustained conflict.

U.S. ground-combat units have weapons to defend themselves from attack by enemy aircraft, as do Navy ships. Many Navy ships have self-defense capabilities in the form of guns and missiles that they can use against attacking enemy aircraft. Army units also employ air-defense systems for the same purpose. Nonetheless, this study focuses on DoD's plans to keep large stocks of fixed-wing tactical aircraft on hand for the foreseeable future to perform both the strike and fighter missions.

Plans for Replacing Combat Aircraft

Inevitably, the planes that perform combat missions today will age over the next decades. Most of them were bought in the 1970s and 1980s. But decisions about how and when to replace them depend on a number of considerations, including future budgets and strategic assessments about the conflicts in which they will be used.

The Bottom-Up Review

When the late Secretary of Defense Les Aspin assumed office in January 1993, he already believed he had a problem with the programs to modernize the tactical air forces. The Bush Administration had given the okay to the services to begin or continue to develop five new tactical fighter or attack aircraft: the F-22, the F/A-18E/F, the A/F-X, the Multirole Fighter (MRF), and the short takeoff vertical landing Strike Fighter (SSF). The Bush Administration had also supported continued purchases of the F-16 fighter for the Air Force. Under the Clinton Administration, DoD personnel estimated that such programs would have cost $320 billion in 1993 dollars (about $340 billion in today's dollars).

Aspin had already heard testimony about the affordability of those planes when he was Chairman of the House Armed Services Committee.[6] As Secretary of Defense, he ordered a comprehensive "Bottom-Up Review" of forces and modernization programs for the U.S. military. The review referred to a "bow wave" —that is, increased funding requirements in that part of the existing plans that was farthest in the future (the bow).

5. For a discussion of the overlap between these forces, see General Accounting Office, *Combat Air Power: Joint Mission Assessments Needed Before Making Program and Budget Decisions* GAO/NSIAD 96-177 (September 1996); Congressional Budget Office *Easing the Burden: Restructuring and Consolidating Defense Support Activities* (July 1994); and *Options for Reconfiguring Service Roles and Missions* (March 1994). At the direction of the Congress, DoD has recently had several reviews of the roles and missions of its forces. Reports discussing those reviews provide DoD's perspective on possible overlaps. See Chairman of the Joint Chiefs of Staff, *Report on the Roles, Missions, and Functions of the Armed Forces of the United States* (February 1993); and Commission on Roles and Missions of the Armed Forces, *Directions for Defense* (May 1995). Neither report recommended major restructuring.

6. See, for example, the statement of Robert D. Reischauer, Director, Congressional Budget Office, before the Subcommittee on Procurement and Military Nuclear Systems and the Subcommittee on Research and Development of the House Committee on Armed Services, April 29, 1992.

The defense plan for future years that was in place when DoD performed its Bottom-Up Review ended in 1999, and the bow wave began at the same time. The review attempted to remedy those problems of affordability by restructuring plans. Hence, with the emphasis on restructuring, the review eliminated two efforts to develop aircraft and canceled further purchases of F-16s.

However, the Clinton Administration did add a new program—the Joint Advanced Strike Technology (JAST) program or the Joint Strike Fighter as it is now called—that would explore ways to build tomorrow's fighters more cheaply. (See Table 2 for more details about future aircraft. For brevity, this study refers to the program as the Joint Strike Fighter when discussing future plans, though discussions of the program's history use the term JAST.)

Table 2.
Tactical Fighter and Attack Aircraft Planned for the Future

Aircraft	Aircraft It Will Replace	When It Will Enter the Force In Bulk	Primary Missions[a]	Procurement Quantity	Procurement Unit Cost (Millions of 1997 dollars)[b]	RDT&E (Billions of 1997 dollars)
			Air Force			
F-22	F-15A-D	2000-2010	Air superiority	438	91 to 108	22.7
JSF	A-10, F-16[c]	Early 2010s	Multirole	2,036	45 to 63	9.8 to 10.7
			Navy			
F/A-18E/F	F/A-18A-D	2000-2005	Multirole	1,000	61	5.7
JSF		Early 2010s	Deep interdiction (or strike)[d]	300	61 to 81	9.8 to 10.7
			Marine Corps			
JSF[e]	AV-8B, F/A-18	Early 2010s	Close air support[d]	642	54 to 68	f

SOURCE: Congressional Budget Office.

NOTES: RDT&E = research, development, test, and evaluation; JSF = Joint Strike Fighter.

a. CBO uses the term "primary missions" to describe those that the planes are most likely to perform or for which they were designed. Aircraft may perform other missions.

b. The low end of the range in the estimates is based on the Department of Defense's price goals. (The DoD estimate was expressed in unit flyaway cost, a lower level of estimation.) The higher number is CBO's estimate of the price of the plane based on historical patterns among price, weight, and performance.

c. May also replace the F-15E and F-117. The Air Force has not made a formal announcement about how it plans to replace its interdiction aircraft.

d. Will be required to perform other missions.

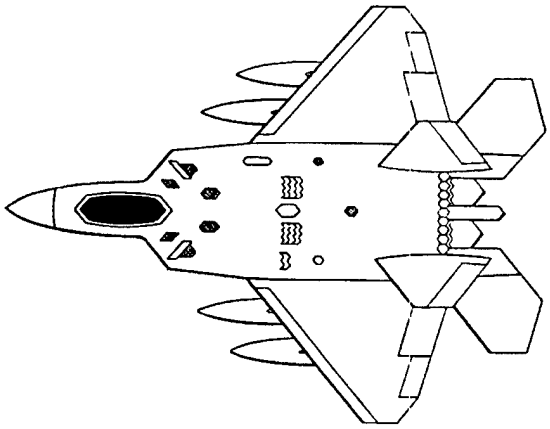
e. The United Kingdom may purchase 60 of these planes.

f. The development share for the Marine Corps is listed under Navy.

The two development efforts that the Administration canceled were the A/F-X and the Multirole Fighter. The A/F-X program was intended to produce a very capable, stealthy strike aircraft to replace the A-6—and possibly the Navy's F-14 fighter—on aircraft carriers. The A/F-X was a joint program that was also targeted to replace the Air Force's F-111, F-15E, and F-117 attack aircraft. The Air Force's MRF program was expected to produce the F-16's successor. The F-16 is the Air Force's current multirole aircraft. A relatively inexpensive aircraft, it was developed so that the service could afford to purchase enough planes to keep up its force levels.

The Administration kept two efforts to develop aircraft: the F-22 and the F/A-18E/F. It did, however, significantly reduce the planned production quantities of the Air Force's highly sophisticated F-22 fighter, apparently based on force reductions. Conversely, it left relatively unscathed the Navy's development effort to produce the F/A-18E/F—a new and improved model of the carrier-based multimission F/A-18.

Illustration 1.
F-22



SOURCE: Drawing courtesy of ©Jane's Information Group 1993, reproduced, with permission, from Jane's *All the World's Aircraft 1993-94* (1993).

The Administration's Plans

The Administration has provided detailed information about its plans for the F-22 and the F/A-18E/F. But fewer data are available about the Joint Strike Fighter, since it has only recently entered DoD's plans. The discussion below of plans for the Joint Strike Fighter is largely based on information that the JSF Program Office has provided either in briefings to CBO or in its solicitation for contracts.

The F-22 to Replace the F-15. The Air Force plans to buy the F-22 fighter to replace its fleet of F-15s (see Illustration 1). Full-scale development began in mid-1991 and is expected to be finished in 2002. Four F-22s—the first of the planned procurement quantity of 438 F-22s—are scheduled to be bought in 1999. Procurement quantities will increase annually until 2003, when the plane reaches a peak procurement rate of 48. If the current procurement plan remains unchanged, purchases of F-22s will continue until 2010.

The Air Force expects the F-22 to improve the capability of U.S. fighter fleets in several ways. It will be stealthy—and hence, more likely to survive in a dense air-defense environment or to be able to shoot down enemy fighters before they can fire back. (See Appendix A for a discussion of stealth and aircraft design.) The F-22 will also cruise at supersonic speeds, without needing to resort to afterburners—a part of a jet engine that adds to the engine's thrust and thus to the speed of the aircraft, but that also uses fuel at a rapid rate. The Air Force expects the F-22's F119 engine to use fuel more efficiently at high speeds than would conventional engines. Moreover, the F-22 will provide displays of information that can easily be read and thus ease the already taxing workload of the fighter pilot. Such displays will provide information about, among other things, the locations of targets, threats, and friendly fighters.

The F-22 will also be an expensive plane. Even if its price grows no more than it already has, the Administration estimates that the F-22 will have a unit procurement cost of $91 million compared with about $46 million for the F-15A-D models. Acquisition costs, which include the funds to develop and procure the fighter, will total from $63 billion—including the $15.7 billion that DoD has already spent—to $70 billion. (The higher cost is CBO's independent estimate for the fighter's price based on past relationships among price, weight, and performance.) Many Members of Congress are concerned about the F-22's price and attempted to

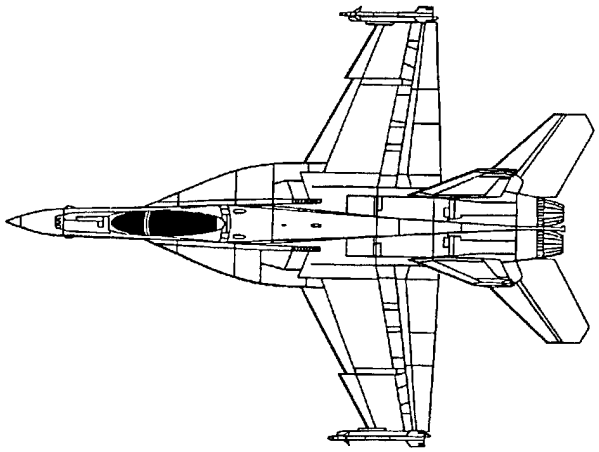
help DoD hold down the fighter's cost. The fiscal year 1997 authorization bill directed the Office of the Secretary of Defense to conduct an independent review of the plane's costs.[7] That review is still in progress.

In addition to concerns about the F-22's price, the Congress has voiced reservations about the phasing of the F-22 program. Specifically, the Senate Armed Services Committee's fiscal year 1996 report on its proposed authorization made the point that the F-22 program would begin significant levels of production before sufficient testing had occurred in the development program (what DoD terms concurrency). As a result, design flaws discovered late in the development process would already have been incorporated in aircraft that were completed early in the production phase. If those problems are severe enough, they could require expensive retrofits and modifications, such as those the B-1B bomber is currently undergoing.

Press reports suggest that the F-22 fighter may already be having problems meeting its development schedule. A recent article in *Inside the Pentagon* says that the F-22's schedule may be revised since avionics developed earlier in the design effort could already be obsolete.[8] Such problems could lead to a delay of a year to a year and one-half in the program, according to the report. The report also indicated that development costs could rise by $1 billion to $2 billion. Neither the Air Force nor the contractors have produced a revised schedule yet, though such a slip in schedule is likely to be a part of the fiscal year 1998 budget submission.[9]

A New E/F Version of the F/A-18. The multipurpose F/A-18 makes up the bulk of the Navy's aircraft fleet and will continue to do so for the foreseeable future. In 1991, the Navy announced plans to develop a new E/F variation of the F/A-18 (see Illustration 2). The E/F version features several modifications: a longer fuselage, a larger wing, and a more powerful engine than the current C/D model has. As a result of the design changes, the plane will be able to carry more weapons than the C/D version and a comparable combat load about 40 percent farther. The plane's new engine should also permit the larger model to be as agile in flight as were earlier models.

Illustration 2.
F/A-18E/F



SOURCE: Drawing courtesy of ©Jane's Information Group 1993, reproduced, with permission, from Jane's *All the World's Aircraft 1993-1994* (1993).

Moreover, the F/A-18's producer is suggesting that the new plane will be stealthier than older models and thus potentially more likely to survive in highly threatening situations. Some analysts suggest that the F/A-18E/F will only be stealthier if it carries no weapons, since nonstealthy weapons carried externally can increase a plane's radar signature, thus raising its visibility to enemy radar and decreasing its survivability. But even if the F/A-18 E/F lacks significant reduction of its signature, it will have other improved systems that counter enemy sensors, thereby increasing its survivability.

The Navy expects to buy 1,000 F/A-18E/Fs beginning in 1997 and continuing through 2015. Because of the large number of planes, the price tag of the F/A-18E/F program exceeds that of the F-22, totaling about $67 billion, even though the F/A-18E/F's unit cost is expected to be lower. CBO's analysis indicates that that estimate is in line with the costs of earlier-model F/A-18s—after adjusting for the E/F's heavier weight.

7. U.S. House of Representatives, *National Defense Authorization Act for Fiscal Year 1997*, conference report to accompany H.R. 3230 (July 30, 1996), p. 36.

8. Elaine M. Grossman, "Air Force F-22 Cost Review Could Result in Higher Bills, Fewer Aircraft," *Inside the Pentagon* (October 31, 1996), pp. 1, 14, and 15.

9. Tony Capaccio, "Cost Study Predicts Worst-Case $15 Billion F-22 Hike," *Defense Week* (December 23, 1996), pp. 1 and 15.

Concerns have also been raised about the benefits of and need for the F/A-18E/F program. A recent General Accounting Office (GAO) report argued that the changes in design required to arrive at the E/F stage of the F/A-18 would lower other performance criteria for the plane and that they were not needed anyway.[10]

Specifically, the GAO report argues that the additional weight that results from increases in range degrades the F/A-18E/F's fighter performance. GAO also argues that whatever improvements do occur are not worth the price increases they would require. The Navy argues that flight test results prove the plane will meet its goals within currently planned prices. Nonetheless, future Congresses and Administrations may revisit the E/F production decision. In fact, the fiscal year 1997 authorization conference report directs DoD to provide a cost-benefit analysis of the F/A-18C/D and F/A-18E/F aircraft by the end of March 1997.[11]

The Joint Strike Fighter: A Model for Common Technologies. As part of the Bottom-Up Review, the Clinton Administration announced a new project: the Joint Advanced Strike Technology program. The JAST program, the Administration promised, would explore common technologies for replacements for Air Force and Navy fighters, and might eventually lead to an acquisition program that would supplant the canceled MRF and A/F-X fighter programs. According to the Administration, that restructuring would eliminate the bow wave in theater air programs that was discussed in the Bottom-Up Review.[12]

The effort to develop a short takeoff vertical landing Strike Fighter was a third program to explore ways of replacing the Marine Corps' AV-8B, a plane that can take off and land vertically from the Navy ships that transport Marine forces to combat. The SSF was not explicitly discussed in DoD's Bottom-Up Review. It did appear in a chart on funding for the Bush Administration's "Base Force" in the report's chapter on resources, but was not included in a similar chart on the Bottom-Up Review forces.

Nonetheless, after the review, the SSF remained a development effort, termed the advanced short takeoff vertical landing (ASTOVL) program, which the Defense Advanced Research Projects Agency and the Department of the Navy managed jointly. But in 1994, the Congress directed the Joint Advanced Strike Technology program to absorb the ASTOVL program.[13] Consequently, the program took on the added task of designing a plane to meet the Marine Corps' short takeoff vertical landing (STOVL) requirement.

The Bottom-Up Review described JAST as a successor to those earlier programs that were aimed at developing and acquiring aircraft to replace retiring fighter and attack aircraft. But initially the JAST was not a true acquisition program. The original objectives for the JAST program were more in keeping with the goal of exploring technology, with an eye toward identifying technologies that might make the Administration's goals for affordability attainable. The purpose of the program was to study the feasibility of a joint-service purchase that would reduce costs through the efficiencies of joint production. The program also planned to explore a variety of procurement reforms.

Recently, however, DoD's expectations of the program have changed. The program office now plans to begin engineering and manufacturing development of a new strike fighter—the Joint Strike Fighter—in 2001 and to start building it around 2005 (see Illustrations 3 and 4). In May 1996, the Administration—responding to Congressional concerns—formally added the program to its list of major acquisition programs.[14]

The Joint Strike Fighter is the largest of DoD's efforts to develop fighter and attack aircraft. The JSF program office indicates that it may begin buying the

10. General Accounting Office, *Navy Aviation: F/A-18E/F Will Provide Marginal Operational Improvement at High Cost*, GAO/NSIAD 96-98 (June 1996). The report, DoD's response, and GAO's response to DoD make interesting reading as a case study on how dependent answers to questions about weapons performance are on detailed assumptions.

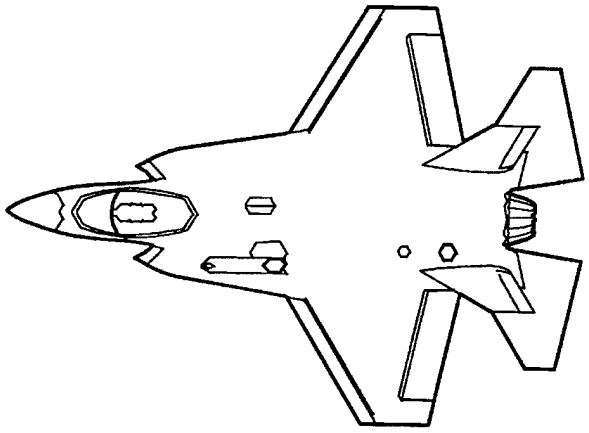
11. U.S. House of Representatives, *National Defense Authorization Act for Fiscal Year 1997*, p. 37.

12. Les Aspin, Secretary of Defense, *Report on the Bottom-Up Review* (October 1993), pp. 35-38 and pp. 107-109. The Clinton Administration used the "bow wave" problem in theater air forces as an example of how the Bottom-Up Review would solve problems caused by the Bush Administration's plans for forces in the post-Cold War period.

13. National Defense Authorization Act for Fiscal Year 1995, H.R. 4301, 103rd Cong., 2nd Sess. (1994).

14. Memorandum from Paul Kaminski, Under Secretary of Defense, to the Secretaries of the Military Departments, May 23, 1996.

Illustration 3.
Lockheed Martin Joint Strike Fighter



SOURCE: Drawing courtesy of Joint Strike Fighter Program Office and Lockheed Martin.

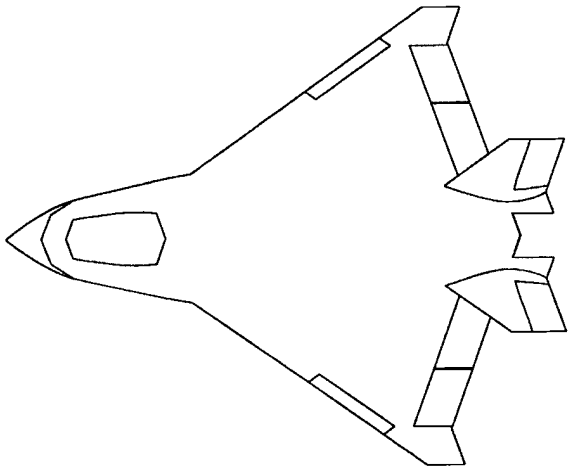
fighter in 2005 with initial purchases of 12 planes divided evenly among the three services. Annual procurement rates would grow to a peak of 170 aircraft. However, because of the large planned procurement, total purchases of the Joint Strike Fighter (about 3,000 planes for the United States) would not be complete until almost 2030. The United Kingdom also plans to purchase the plane.

The Department of Defense has not yet given an estimate for the total program costs of the Joint Strike Fighter to the Congress. But in its instructions to aerospace companies competing for the contract to develop the concept, the program office included estimates of its goals for flyaway costs of the fighter. Based on those goals, total acquisition costs would be $165 billion; CBO's own estimate is higher—$219 billion.

Despite claims by the Clinton Administration that its plan will eliminate the tactical aviation bow wave, the affordability of plans for tactical aircraft is still a worry for the Congress. Representative Curt Weldon, Chairman of the Subcommittee on Military Research and Development of the House National Security Committee, recently pointed out that such tactical aircraft programs will cost as much as those in the plans that were termed unaffordable in the Bottom-Up Review. Reports on the House and Senate authorizing bills for defense for 1996 also expressed concerns about tactical aviation. In addition, language in Congressional reports on the fiscal year 1997 defense budget raised concerns about plans for modernizing tactical fighter and attack aircraft.

The Joint Strike Fighter program recently held a competition to determine which aerospace companies would develop the concept for the plane. The solicitation for bids for the competition drew responses from five military aircraft producers. Two proposals from Lockheed Martin Corporation and the Boeing Company were selected. The losing bid was submitted by a team composed of McDonnell Douglas Aerospace, Northrop Grumman Corporation, and British Aerospace Defence Limited. Industry interest is understandable. If the program results in development of a family of aircraft that perform the spectrum of missions currently envisioned, the Joint Strike Fighters will make up more than half of all U.S. fighters produced in the years between 2002 and 2020. After 2010, when the production of F-22s ends, JSFs and the Navy's F/A-18E/F may be the only U.S. fighters in production. Thus, if an aircraft producer is left out of the JSF program, it could signal a lost future in tactical aviation.

Illustration 4.
Boeing Joint Strike Fighter



SOURCE: Drawing courtesy of Joint Strike Fighter Program Office and the Boeing Defense and Space Group.

Conversely, a contract to build a Joint Strike Fighter could reap unprecedented sales for the winning company or companies. Micky Blackwell, president and chief operating officer of Lockheed Martin's aeronautical sector—and a representative for one of the companies that submitted winning proposals—presented industry's view of the sales potential associated with the JSF program: "The JAST program could end up being a trillion-dollar program. We are talking lots of planes, a lot of money."[15]

Others in the industry believe the $1 trillion figure is too high. Blackwell's estimate is apparently based on the belief that the Joint Strike Fighter would replace an even larger share of U.S. tactical fighter inventories than currently envisioned, and on the assumption that it would be sold widely in foreign markets. The same article suggested that other aerospace observers doubt the program would ever reach that size. For example, according to the same article, Richard Aboulafia, an analyst with Teal Group, said, "If every other fighter program in the world collapses, including indigenous ones, and only JAST is left, then, you could be talking about a trillion dollar market."[16] Nonetheless, according to industry and government sources, the JSF program will be worth hundreds of billions of dollars to the winning contractor team.

Given the importance of the JSF's role to the future of tactical aviation, considerable interest in the program is merited. The outcome of the JSF program's efforts to produce affordable fighters will determine whether future Administrations can keep tactical fighter fleets at their current levels or if they will have to reduce force structure to stay within future budgets. That development, in turn, may bear on the national security strategy of future Administrations, since the strategies the United States can contemplate depend on the size and capability of the U.S. force structure that carries them out. Not least, because the JSF's schedule and production quantities are entwined with the plane's cost, Congressional and Administration scrutiny of the JSF's future affordability may be warranted.

15. Theresa Hitchens and Frank Oliveri, "Company Predicts Windfall for JAST Winner," *Defense News* (January 29, 1996), p. 1.

16. Ibid., p. 1.

Chapter Two

The Role of Tactical Aircraft in Carrying Out National Security Strategy

To gain a proper prospective, one must view tactical aircraft needs in the context of the threats the United States might face and the national security strategy for dealing with them. Both threats and strategy have changed dramatically over the last seven years. During the Cold War, U.S. fighter forces were sized and structured to fight a conventional war in Europe with the former Soviet Union. The Soviet military had more than 6,000 combat aircraft and engaged in costly development and modernization efforts to ensure that its fighters would keep improving. The Soviets had also invested in what was probably the best air-defense network in the world.

After the Soviet Union fell, U.S. leaders needed a strategy that reflected a new world order. But given that the old world order had collapsed, for what conflicts should the United States prepare? It is still not an easy question to answer.

Establishing the Base Force and the Bottom-Up Review

In 1991, the Bush Administration, fresh from its success in "Desert Storm" (the conflict with Iraq) announced that it would structure U.S. forces to focus on fighting similar wars—namely, regional conflicts. Under the direction of its Chairman, General Colin Powell, the Joint Chiefs of Staff laid out plans to restructure U.S. military force structure—to a "Base Force"—to reflect that change in national strategy. Department of Defense personnel, describing the new strategy, suggested that the specific locations of those future conflicts could not be determined precisely. But for planning purposes, the department assumed that such wars would take place in the Middle East—against either Iraq or Iran—and on the Korean Peninsula.

The Threat of Regional Conflicts

The strategy called for major changes in the structure of U.S. fighter forces. Under the Base Force, U.S. fighter forces were to be restructured. They were expected to include 26 Air Force wings and 13 carrier air wings in the Navy, down from 37 and 15, respectively, in the late 1980s.

In October 1993, the Clinton Administration laid out its plans for defense in a report it called the Bottom-Up Review (see Chapter 1). The review provided an estimate of the major forces needed to fight in a single major regional conflict, a war similar in scope to the Iraqi war. The building blocks for the major regional conflicts included several elements containing fighter and attack planes: 10 Air Force fighter wings, four to five Marine Expeditionary Brigades, and four to

five Navy aircraft carrier battle groups.[1] Since the Administration planned to retain the forces to fight in two regional wars at almost the same time, the Department of Defense's planned forces were roughly double those "building blocks."

For tactical fighters, the review called for 20 wings in the Air Force and 11 carrier air wings—six and two fewer, respectively, than the Base Force. Marine Corps air forces were discussed only in terms of the ground units they supported, and those units were ultimately kept at Base Force levels, though the Bottom-Up Review initially appeared to recommend reductions.

Other Threats

Although DoD's new strategy calls for fighting regional conflicts, the capabilities of other powers are also important. The United States has recently enjoyed relatively cordial relationships with Russia, the inheritor of the bulk of the forces of the former Soviet Union. But because of the size of Russia's military potential and the recent Cold War, U.S. military planners will probably continue to consider Russian forces as a potential threat.

Planners are also likely to keep a close eye on China's military potential. China represents the one remaining communist country with what political scientists refer to as "great power" status—that is, countries that possess powerful military and economic capabilities, wide regional or global foreign policy interests, and the willingness to defend them. More important perhaps than China's status as a communist power is its rapidly growing economy. The Chinese economy and markets may give it the economic wherewithall to emerge as a significant military threat if it chooses to make larger military investments.

To deal with such uncertainties about a bewildering array of potential enemies and possible scenarios, some DoD planners are evaluating alternative U.S. forces against a new scenario, called the Generic Composite Scenario. That concept, originally developed by the Air Staff and called the "regional conflict model," attempts to deal with uncertainties by constructing an illustrative baseline for the threat. As the Congressional Budget Office understands it, analysts using that method fold the potential capabilities of a number of countries into a one-threat scenario. The methodology uses a database of forces and targets from 17 countries. From that database, it creates a threat that is more than double the average for a variety of target or force categories. The model thus assumes that the threat may equal or exceed 90 percent of the targets and forces of the countries in the database.

How Great Is the Threat from Foreign Fighters?

Sizing U.S. tactical forces to meet two regional contingencies requires an assessment of their potential adversaries in such conflicts. How many aircraft do potential enemies possess and how good are they?

Surveying the Size of Fighter Inventories

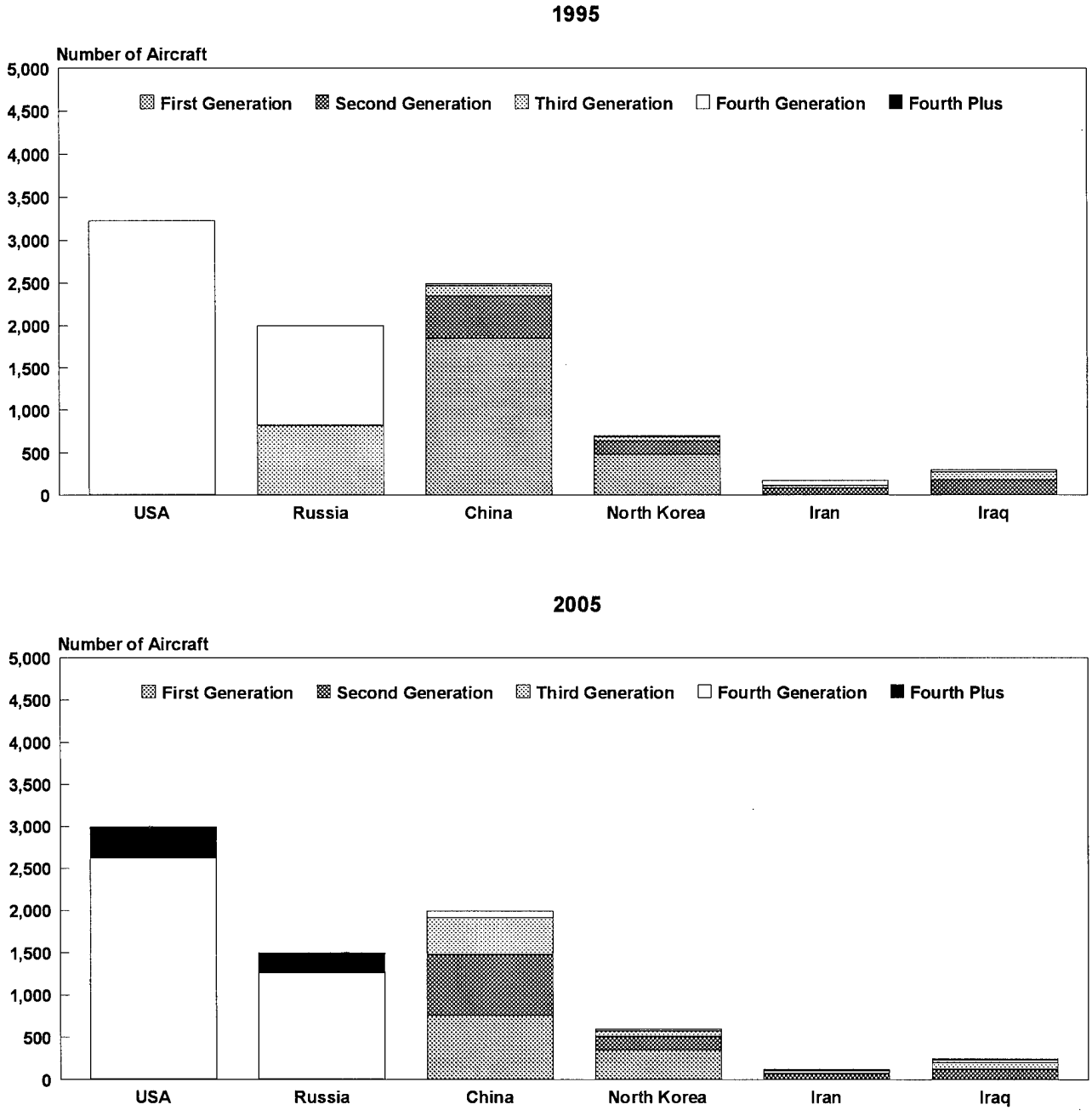
If the two major regional contingencies—war in the Middle East with Iran or Iraq or war in Southeast Asia with North Korea—remain the basis for planning, then U.S. fighter forces would face relatively modest numbers of enemy fighters (see Figure 1). In 1995, Iran's fighter inventories totaled 175, Iraq's 300, and North Korea's about 700—compared with the more than 6,000 fighters that belonged to the former Soviet Union in the 1980s.[2]

The United States and its regional allies could in fact field far more planes in a conflict. By the turn of the century, after planned reductions in force struc-

1. Les Aspin, Secretary of Defense, *Bottom-Up Review* (October 1993), p. 19. The review's building blocks in a major regional conflict also included four to five Army divisions and 100 Air Force long-range bombers.

2. Unless otherwise specified, the estimates of modernity and fighter forces of countries that pose potential threats discussed here are based on analysis by the Office of Naval Intelligence, which was discussed in the recent publication, *Worldwide Challenges to Naval Strike Warfare* (January 1996). It is the only U.S. government source for detailed, unclassified fighter inventory projections for potentially threatening countries. The Office of Naval Intelligence apparently aggregated data from the Defense Intelligence Agency to come up with its estimates.

Figure 1.
Size and Level of Modernization of Fighter Inventories in Selected Countries



SOURCE: Congressional Budget Office using data from Office of Naval Intelligence, *Worldwide Challenges to Naval Strike Warfare* (January 1996).

NOTE: Fourth Plus equals F-117s, F-22s, F/A-18E/Fs, and JSFs.

ture are completed, the United States will possess about 3,500 fighter or attack aircraft (about 3,100 planes are fighters or multirole aircraft, categories similar to those shown for other countries). It could probably field about 1,000 of those planes to each war (or roughly double that number if it was to fight in only one theater).[3]

Allies would contribute to those numbers: for example, South Korea and Saudi Arabia possess 385 and 235 planes, respectively. Other allies might also contribute. To cite a couple, the United Arab Emirates and Oman have 78 and 27 planes, respectively, that they could use if a conflict similar to the war with Iraq arose.

Modernizing Fighter Inventories

Yet simple counts of aircraft inventories may be misleading indicators of combat potential. Large inventories of obsolete aircraft may simply present a "target rich" environment for today's modern fighters and surface-to-air missiles. One way of evaluating the military potential would be to consider the level of modernization—namely, when were the planes developed and purchased?

Predicting accurately the size and nature of forces that might be needed when the location and timing of the conflict are unknown is exceedingly difficult. Moreover, substantial uncertainty exists as to how much modernization will occur worldwide before planes that the United States is developing today can be fielded. Nonetheless, planners for DoD and the services must make decisions about modernization.

Recent statements by DoD leaders reflect considerable pessimism about current and future modernization of foreign fighters. For example, Vice Chairman of the Joint Chiefs of Staff, General Joseph Ralston, suggested in recent testimony before the House Committee on National Security that advanced fighters in foreign countries continue to improve and proliferate.[4] The General's presentation included a chart that indicated inventories of modern foreign fighters could total 5,900 planes.

General Ralston's estimate, however, appears to tally the planes of every country in the world except the United States. It includes modernized fighters possessed, for example, by some of the United States' closest allies: the United Kingdom, Germany, France, and Canada. It is difficult to imagine a conflict in which U.S. forces would face any—much less most—of those nations simultaneously. Indeed, they are more likely to fight on the side of the United States.

The analysis by the Office of Naval Intelligence focuses more narrowly on five selected countries: Russia, China, Iran, Iraq, and North Korea. (Figure 1 includes the fighter "generations" for the planes in the inventories of those countries and those of the United States.) The generational breakout is intended to capture the level of technology incorporated in the airplanes. The Navy's study shows the size and generational mix in the fleets of the five countries discussed above for 1985 and 1995 as well as projections for 2005.

Reviewing the Various Generations of Fighter Aircraft

What are the planes that make up the various generations?[5] First-generation aircraft—including the MIG-15 to MIG-19 and U.S. century series fighters—were designed during the 1940s and 1950s. Although they are still found in fighter inventories worldwide, older planes probably have limited combat potential when confronting more modern fighters, since they may suffer from several disadvantages. For example, they may carry less sophisticated munitions and have less capable sensors.

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3. Considerable uncertainty exists, though, about how many planes could actually be sent to war. Although the United States will have more than 3,500 planes in inventory, some of those planes perform support roles and are not likely to be used in actual combat. Of the combat aircraft, some might not be ready to fight. Aircraft deployments also depend on a number of other factors such as airlift, prepositioned stocks of equipment, and the availability of basing, that are beyond the scope of this paper.

4. Joint statement of Paul Kaminski, Under Secretary of Defense for Acquisition and Technology and General Joseph Ralston, Vice Chairman of the Joint Chiefs of Staff, before the Subcommittees on Military Research and Development and on Procurement of the House Committee on National Security, June 27, 1996.

5. This discussion is based on the taxonomy provided in several Brookings publications that seems to mesh with the generations discussed in the Office of Naval Intelligence publication. See, for example, Robert P. Berman, *Soviet Air Power in Transition* (Washington, D.C.: Brookings Institution, 1978).

Second- and third-generation aircraft may provide somewhat more military capability, especially if they have gone through extensive modifications since they were built. Designed during the 1950s through 1970s, those generations include the MIG-21-MIG-27 series designed by former Soviet Union's Mikoyan Design Bureau; F-4s and A-7s built by the United States; and the European designed Mirage 3, Mirage 5, Tornado, and F-1. Fourth-generation fighters, designed during the 1960s and 1970s, include the U.S.-designed F-14, F-15, F-16, and F/A-18; the Soviet-built SU-27 and MIG-29; and the European Mirage 2000. Fourth-generation aircraft usually have more sophisticated avionics than their predecessors, more powerful engines, and are able to operate more capable missiles.

Planes developed during the 1980s and 1990s are fifth-generation aircraft. They include the F-22 aircraft for the United States and foreign fighters such as the SU-35, Rafale, and European Fighter Aircraft (now designated EF-2000).[6] Fifth-generation aircraft continue the trend in improving avionics. Some new designs will incorporate improvements in propulsion technology, and some will be stealthy.

Modernization—measured by generational percentages discussed here or average age discussed later—is a useful, but not foolproof, proxy for capability. Older aircraft—such as Air Force F-111s and the Navy A-6s—were prized possessions until fairly recently, largely because they possess longer ranges or more sophisticated sensors than some newer U.S. tactical attack aircraft. But those aircraft represent the exceptions, and newer planes are generally more capable.

Sizing Up Russian and Chinese Air Forces

Both Russia and China could field significantly more aircraft than regional powers, though fewer than the United States or the former Soviet Union. Russian air forces (including Air Force, Navy, and planes held by Russia's strategic Air Defense forces) contained about 2,000 fighter aircraft in 1995.[7] China possessed more planes with a total of about 2,500 in 1995, according to the U.S. Navy. Both countries' aircraft inventories, however, are made up of earlier generation planes than those of the United States.

Russian Air Forces. Russia has the most modern inventories of the potential adversaries the Navy listed. Its fleet consists entirely of third and fourth generation aircraft, and almost 60 percent of Russian fighters are fourth generation. Large reductions in forces and the retirement of older Russian aircraft at the end of the Cold War may have aided that high level of modernization. Many of the older planes may also have become the property of the Commonwealth of Independent States—states that formed part of the former Soviet Union. Russia inherited only about 60 percent of the former Soviet Union's combat aircraft. According to the Navy estimates, Russian fighter inventories in 1995 were about half the size of Soviet fighter inventories in 1985.

The Navy expects that Russia will continue to modernize and reduce forces over the next decade, though at a slower pace. By 2005, Russian fighter inventories might be made up almost entirely of fourth-generation planes with a smattering of more advanced fighters.

Chinese Air Forces. The Chinese also appear to have accepted large-scale reductions in force over the last decade, perhaps to pay for modernization. Their fighter inventories declined by about 45 percent during that period—from 4,500 in 1985 to 2,500 in 1995. Even so, China's 2,500 plane force consists largely of older aircraft. Only 6 percent of the 1995 inventory is third- and fourth-generation planes, and almost three-quarters of China's fleet is composed of planes that have 1950s vintage designs. A RAND publication—which also

6. Though the Chinese F-10 would be included in the fifth generation based on the timing of its design and fielding, the Office of Naval Intelligence (ONI) appears to be including it in the fourth generation. ONI probably did this to reflect the relatively limited capabilities of this indigenously produced fighter.

7. Research literature reveals wide disparity in the counts of foreign fighters. To be consistent, CBO uses the Navy publication for this discussion because it provides unclassified U.S. government fighter projections for foreign countries. But other sources, such as the International Institute for Strategic Studies' annual publication, *The Military Balance*, provide considerably different totals. One publication suggests that as recently as 1994 Russian combat holdings could have been much larger, totaling about 3,900 planes, and drawing down to about 3,100 planes by 1996. The publication suggests a plan to draw fighter inventories down to about 2,200 planes by the turn of the century—numbers more consistent with the Navy's estimate. Nonetheless, concerns remain about disparity in those force counts. See the Center for Science and International Affairs, *The Arms Production Dilemma: Contraction and Restraint in the World Combat Aircraft Industry*, Randall Forsberg, ed. (Cambridge, Mass.: MIT Press, 1994).

provides a useful discussion of foreign fighter force levels and modernization—indicates that planes of that generation would probably have little combat utility if pitted against more modern aircraft.[8]

The Navy expects the pace of modernization for Chinese fighters to pick up over the next decade as the Chinese begin producing the fourth-generation F-10. That plane incorporates modern technology, some of which was acquired through Israel based on the design of Israel's canceled Lavi fighter and some of which comes from Russian technology exports.[9] Despite those trends in modernization, by 2005 modern planes will make up only about a quarter of China's fighter inventories according to the Navy's estimates. Moreover, the Navy expects the Chinese to continue trading off quantity for quality, with a further drop in inventory levels to about 2,000 planes.

The Air Forces of Regional Powers

Generational breakouts also provide more information about the fighter inventories of the regional powers: North Korea, Iran, and Iraq. Like the Chinese, most of North Korea's planes are old or based on very old designs. About 70 percent of the 700 fighters North Korea possessed in 1995 were first-generation designs, and less than 10 percent were the more modern third- and fourth-generation planes. The Navy expects modest modernization to continue in North Korea over the next decade, resulting in about 15 percent of North Korea's 2005 inventory being made up of relatively new designs. The Navy also expects North Korean inventories to drop by about 100 planes during this period—or to about 15 percent less than the 1995 level.

Iran and Iraq have smaller fighter inventories than North Korea, but they are more modern. In 1995, Iran had about 175 fighter aircraft—about 25 more than it had a decade earlier. More than half of the planes were third- and fourth-generation fighters. The Navy expects Iran to continue to modernize its forces slowly so that by 2005 it could field a squadron or two of advanced fighters. The price of that modernization might be a reduction in force of about 50 planes, according to the Navy's estimates.

Iraq had about 600 planes in 1985. Some of those aircraft were destroyed in the Gulf War or were flown to Iran, which never returned them. In 1995, Iraq had some 300 fighters. About 40 percent of them were third- and fourth-generation planes. The Navy expects Iraq to modernize over the next decade, perhaps increasing the percentage of modern planes in its fleets to about 50 percent.

Iraq's ability to modernize is believed to depend heavily on two sets of sanctions that have been imposed on that country by the international community. The first are sanctions that attempt to prevent arms sales to Iraq. The second set limits Iraqi oil sales. Restrictions on oil sales limit modernization, since they prevent the Iraqis from using oil revenue to purchase arms. Even if current sanctions end, the negotiations that end them might require Iraq to agree to limits on weapons procurement. An agreement might well not halt purchases, since countries often find ways around such promises, but it might make them smaller.

Fighter Exports: Are They a Major Concern?

Could an oil-rich regional power acquire a fleet of modern aircraft that could match those the United States could deploy? It is unlikely. During the Cold War, the Soviet Union was the major exporter of weapons to countries hostile to U.S. interests. Though its military technology was less sophisticated than that of the United States, the Soviet industrial base produced more sophisticated weapons than that of any other unfriendly nation. None of the countries commonly viewed as potential threats today have the resources to devote to modernizing their fighters that the Soviet Union had.

Russia, which retained the larger share of the military potential of the former Soviet Union, has much less ambitious plans for aircraft design and production. A fifth-generation fighter that DoD once anticipated would be delivered early in the next decade is unlikely

8. Christopher J. Bowie and others, *Trends in the Global Balance of Air Power* (Santa Monica: RAND Project Air Force, 1995), pp. 37-38.

9. For an interesting discussion of the Lavi program, see Dov Zakheim, *Flight of the Lavi: Inside a U.S.-Israeli Crisis*, (Washington-London: Brassey's, 1996).

to become operational before 2015.[10] Cuts in Russian domestic production may also result in a smaller fighter production base. In turn, a smaller base might produce fewer modified fourth generation aircraft for export.

Potentially threatening countries might seek to purchase more modern aircraft from U.S. allies. *The Gray Threat*, a publication by RAND that argues for the F-22, compares the potential performance of three fighters—the Swedish Grippen, the French Rafale, and the EF-2000—with the capabilities of the F-15 and F-16.[11] The analysis suggests that the Rafale offers and the EF-2000 may offer substantial improvements over the F-16 and that they have capabilities roughly equal to the F-15E. RAND claims that the Grippen, a smaller plane, would nonetheless have capabilities that exceed those of the F-16.

Some U.S. aircraft builders dispute those estimates. Lockheed Martin, the F-16's manufacturer, argues that the RAND study used the thrust-to-weight ratio—a measure that can translate into speed and agility—of the block 42 F-16, which has the lowest thrust-to-weight ratio of any F-16 produced. It suggests that current F-16s have ratios that are 20 percent higher—in other words, comparable to other top fighters.

Whatever is the right answer about aircraft performance, part of the motivation on the part of American aircraft manufacturers in those disputes can be traced to their desires to sell U.S. aircraft abroad. The United States will probably produce a large portion of the planes that modernize foreign fighter forces. Those planes will, of course, be sold to countries that are U.S. allies at the time of the sale. But the United States has faced the possibility of confronting its own aircraft in war in the past when friends became enemies. A good example of that about-face is Iran. Under the rule of Mohammad Reza Shah Pahlavi, Iran purchased top-of-the-line U.S. aircraft that had recently been delivered when the 1979 revolution ushered in Islamic fundamentalist rule.

Simple economics suggests that regional powers are unlikely to deploy large numbers of advanced aircraft. Acquisition costs may simply be too high for any but the wealthiest nations to increase greatly their reliance on air power.

Why Should the United States Keep Such Overwhelming Superiority in the Air?

Even if the enemy forces that U.S. tactical fighters face are no match for them in either number or quality, the United States may choose to invest in air power for other reasons. The United States relies on tactical aircraft more than other countries. As a result of past investments, the United States dominates world air power, if only because it is richer than other countries and spends much more on defense than other countries. U. S. reliance on aircraft also derives from their relative mobility. The United States expects to fight on foreign soil and must purchase weapons that can be transported easily. Also, U.S. supremacy in the air may help to offset less favorable balances on the ground. Aircraft also can attack enemy forces before a ground campaign begins, thus increasing the likelihood of an early U.S. victory with lower casualties.

The United States may also place relatively more emphasis on tactical aircraft today than it did in the past. For one thing, tactical aircraft are easier to transport than ground forces, which may make them available more quickly if conflict occurs in an unexpected location, though tactical aircraft do require airlift, sealift, or prepositioning of considerable tonnage in support equipment. Their mobility may make them particularly useful in the rapidly arising wars in DoD planning scenarios. Aircraft based on aircraft carriers or accompanying ship-transported Marine Corps ground troops would be particularly useful in conflicts that arise suddenly and where landing rights at air bases prove difficult to secure. Some analysts, however, would argue that recent experiences, such as the war with Iraq, suggest that U.S. forces would have longer to prepare for and deploy forces to war than current sce-

10. Benjamin Lambeth, *Russia's Air Power at the Crossroads* (Santa Monica: RAND Project Air Force, 1996). This recent RAND publication suggests that Russia lacks funds for significant modernization of its air forces. See also Forsberg, ed., *The Arms Production Dilemma* for a useful discussion of plans for fighter production in Russia and other countries.

11. Mark Lorell and others, *The Gray Threat: Assessing the Next-Generation European Fighters* (Santa Monica: RAND Project Air Force, 1995).

narios assume. But potential foes may have learned lessons too leaving little time for a lengthy U.S. build up. Some proponents of air power believe that the advantages of preceding any action on the ground with air attacks was also a major lesson from the war with Iraq.

Air campaigns also lower the risks of U.S. casualties, a relevant issue when future contingencies might occur in areas of the world where some citizens may question whether the interests at stake are worth the price of lives of U.S. troops. Indeed, in some ways the U.S. population is more sensitive to casualties in general today than it was in the past, in part because media coverage brings war into the living rooms of the United States nightly. In fact, even in conflicts in which U.S. interests are clearly at stake, the issue is inevitable.

U.S. leaders have used air power in situations in which they were reluctant to commit ground forces. For example, air power was used in bombing Libya in 1986, more recently in the former Yugoslavia, and to enforce international sanctions on Iraq.

Other Factors Affecting U.S. Fighter Requirements

In determining requirements for tactical aircraft, the Department of Defense must consider factors beyond modernizing enemy fighters. Some factors such as proliferation of advanced surface-to-air missiles systems and improvements in enemy air-launched missiles could make the job of U.S. combat air forces more difficult in the future.

U.S. fighter forces possess, however, a number of benefits fighter forces of other countries may not enjoy. For instance, U.S. military personnel are often better trained than the personnel of many potential regional adversaries. Their weapons are also in better repair. In addition, the United States invests in systems that provide better command, control, communications, and intelligence—such as the E-8 Joint Surveillance Target Attack Radar System (JSTARS) aircraft that locate targets on the ground and E-3 airborne warning and control system (AWACS) planes that provide information about planes in the area.

Factors That Complicate the Task of U.S. Air Power

U.S. fighter forces may find it costly to achieve air supremacy in regional conflicts if Russia and other countries that were part of the former Soviet Union sell Soviet style surface-to-air missiles (SAM). According to service briefings, U.S. tactical aircraft could face substantial increases in the level of the surface-to-air threat. For example, an Air Force briefing indicates that by 2005 some 23 countries may have advanced surface-to-air missile systems compared with 14 today. (That Air Force estimate is of all worldwide holdings, including those of the United States, as well as a number of friendly nations. Presumably the United States benefits when its allies possess modern weapons.)

The Navy, whose publication offered a less pessimistic view of fighter threats than the Air Force, expressed more concern about ground-based air defense systems. For instance, the Navy suggests that enemy ground-based weapons have been more deadly to the United States and its allies than enemy aircraft. The Office of Naval Intelligence points out that ground-based missiles or guns shot down almost all of the allied aircraft lost to known causes in the war with Iraq; yet enemy aircraft shot down only one coalition plane out of 25 planes lost to known causes. In fact, during the war with Iraq, very few allied aircraft—only 38 fixed-wing aircraft—were lost to any cause at all, and only 48 additional planes were damaged.[12] The official Air Force history of the air campaign in the war with Iraq, the *Gulf War Air Power Survey*, points out that that rate is considerably lower than during the Vietnam War. It represents a loss of only one plane for every 1,800 combat sorties.

The Navy publication also expresses concerns about further advances in surface-based air defense systems that will make them more challenging to U.S. aircraft. SAM systems could become more mobile, with better missiles, and greater tracking capabilities. As a result, those systems could be harder to detect and defeat. Modernizing surface-to-air missile systems—at least cheaper, hand-held weapons—might be a less complex and less costly way for enemies to upgrade

12. Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report* (Department of the Air Force, 1993), p. 61.

their counter-air capabilities than building sophisticated fighter fleets.

Conversely, both the Navy and RAND's *Trends in the Global Balance of Air Power* argue that defending a given airspace with fighters may be less costly than with ground-based air-defense systems since many SAMs may be needed to cover the same volume as a few fighters.[13] That theory may also apply to "man-portable" systems, even though they are very inexpensive individually compared with larger air defense systems. Nonetheless, their low price makes proliferation of hand-held weapons virtually inevitable.

The war with Iraq proved that a country may have modern air defense systems but not necessarily the capability to operate them with skill (it may also suggest that U.S. analysts overestimated the capability of Soviet weapons). Many U.S. defense analysts expected Iraq's Soviet-style air defense system to prove highly challenging to U.S. aircraft, since the former Soviet Union was believed to field the most effective air defense networks. Yet Iraq's air defense system was largely incapacitated within days of allied attack, not an outcome one would have predicted based on U.S. assessments of the former Soviet Union's air-defense capabilities. (The Soviets may, however, have planned to field a much denser SAM threat than that fielded by the Iraqis.) The system might have survived longer if it had been operated by highly trained personnel and defended by fighter aircraft. Increased automation in new air-defense networks might make it easier for countries that spend limited amounts on troop training to operate them effectively.

Hostile countries might find less costly ways of modernizing their air forces than purchasing sophisticated and costly aircraft. Improved air-to-air missiles, if proliferated, might provide more air-to-air capability to less capable fighter aircraft. The Air Force suggests that countries possessing advanced air-to-air missiles will rise from five today to 25 by 2005 (as before, the Air Force counted the allies of the United States).

The Navy also expressed concerns about current and future air-to-air missiles. According to the Navy, two short-range air-to-air missile systems—the Russian AA-11 and Israel's Python 4—exceed the capability of the United States' short-range Sidewinder missile. Those missiles have longer ranges and "[If] integrated with a helmet-mounted sight. ...can fire at targets approaching 90 degrees off the fighter's nose."[14] The British ASRAAM (Advanced Short-Range Air-to-Air Missile, a program the United States abandoned in the early 1980s) may be an improvement over those missiles if it is fielded.[15]

Short-range missiles usually are heat-seeking. They are useful at "visual" ranges—that is, when the pilots of battling fighters can see each other at distances of several miles or less. The United States has emphasized fighting from longer ranges and has focused development funding on missiles that operate from medium ranges (also called beyond visual range) of 25 to 30 miles or more. The product of that focus, the Advanced Medium-Range Air-to-Air Missile (AMRAAM), is currently superior to other countries' missiles, largely because its active radar seeker provides the missile with targeting information rather than relying on data from its aircraft. The AMRAAM-armed aircraft can "launch and leave," or break off after launching the AMRAAM and leave to fight another engagement or get out of harm's way.

Several countries have development efforts under way to produce AMRAAM competitors. Those efforts include the French medium-range *Missile d'Interception et de Combat Aérien* (MICA), which is an air combat and air intercept missile, and the European FMRAAM (Future Medium-Range Air-to-Air Missile).[16] Either of those missiles could be sold to countries unfriendly to the United States. Moreover, their developers suggest that they will have capabilities that match or exceed those of the United States' AMRAAM, though some may doubt such claims, at least for MICA. According to the Navy, Russia also has several medium-range, launch-and-leave missiles under develop-

13. Bowie and others, *Trends in the Global Balance*. This publication offers a useful discussion of air power and air defense and provides the underpinning for much of this discussion of factors affecting air power.

14. Office of Naval Intelligence, *Worldwide Challenges*, p. 20.

15. *Jane's Air Launched Weapons* (Surrey, United Kingdom: Jane's Information Group, 1996). The United States signed an agreement with the United Kingdom that it would pursue the medium-range, radar-guided AMRAAM missile, while a European consortium pursued the shorter-range ASRAAM air-to-air missile. Upon production, partners in the agreement might purchase each other's missiles.

16. A heat-seeking MICA is also slated for production.

ment. Of course, many of those missiles might never be developed, never perform to specification, and even if they are developed, might require extensive integration to work on earlier generations of aircraft.

What Makes U.S. Air Power More Effective?

Several factors may increase the effectiveness of U.S. air power. Those factors include access to plenty of information about enemy forces and extensive training.

Both the Navy and the Air Force have expressed concerns about the possibility that regional adversaries will improve their ability to control forces in the field and develop better command, control, communications, and intelligence (C^3I) systems. For the foreseeable future, however, the United States has overwhelming superiority in systems that provide its forces with information about the shape of the battlefield.

For example, no other potentially threatening country, including the former Soviet Union, has systems to rival the E-3 airborne warning and control system.[17] AWACS can keep track of the location of a number of aircraft and relay to U.S. fighters the location of friendly and enemy planes in a given area. JSTARS provides similar information about targets on the ground. According to an Air Force study, a JSTARS prototype was so successful in the war with Iraq that the United States was able to track the movements of Iraqi reinforcing columns. The United States also invests heavily in satellites that provide impressive arrays of data about the battlefield.

In addition to all of those advantages in C^3I, U.S. tactical aircraft are aided by stealthy long-range bombers and ship-launched cruise missiles that might defeat even improved enemy air defenses. Also, more than any other country's fighters, U.S. planes can count on receiving aerial refueling from tanker aircraft, thus extending their ranges. That advantage might compensate for improvements in the ranges of enemy fighters and attack aircraft. It also could compensate if U.S. development efforts result in planes that have shorter ranges than those in the fleet today.

The United States will also continue to invest in improvements to the weapons deployed on its fighter aircraft, and it stands an excellent chance of countering many of the improvements in that area by potential enemies. DoD's development efforts currently emphasize improving air-to-surface munitions, though the department suggests that improvements to medium- and short-range air-to-air missiles are also on the drawing boards.[18]

In fact, several of those development efforts might compensate for improved enemy air defenses by permitting planes to launch their weapons while still out of the reach of surface-to-air missiles. Weapon programs might also enhance aircraft survivability in other ways by, for example, making multiple kills per pass possible, thereby reducing the number of passes for a given threat. Improvements in weapons might compensate if funding problems reduce the number of U.S. fighter aircraft.

Furthermore, the United States keeps its forces at a high level of readiness—perhaps as high as any potentially hostile country and much higher than most.[19] For the last several decades, DoD has placed the highest priority on "readiness"—that is, being able to fight well on short notice. Well-trained troops with fully functioning equipment are the underpinnings of a ready force. U.S. pilots receive impressive training in basic and advanced flight skills. The United States also allocates substantial resources annually to make sure that pilots receive plenty of flight hours and are well trained. U.S. Air Force fighter and attack pilots in operational squadrons fly on average about 19 hours a month, and pilots in the Department of the Navy fly about 22 hours per month. Those averages are probably higher than those in most developed nations and probably even higher in comparison to the flying patterns of potential regional adversaries. Some analysts have argued that having experienced, highly trained pilots is at least as

17. The former Soviet Union developed and fielded a plane in the 1980s, which performs a similar mission to AWACS, but it probably is not as sophisticated or as capable as AWACS. Most of those planes are now in Russian inventories.

18. For a helpful discussion of these programs, see Bert H. Cooper, Jr., *Missiles for Standoff Attack: Air-to-Surface Munition Programs* (Congressional Research Service, November 1996).

19. Even among friendly countries, probably only the Israelis and perhaps the British provide levels of training that might equal those provided by the United States.

important to combat outcomes as possessing sophisticated fighters.

In addition, the United States possesses an advantage over potential enemies in the skills of the personnel who maintain its complex aircraft fleets and in the stocked level of spare parts. Fighters, the sports cars of the air world, are not useful for long if one lacks the expertise to repair them or cannot get replacement parts for them when they break down. For example, the F-16, a very dependable U.S. fighter, flies only about four hours before some component needs repair or replacement. Such repairs can keep fighters out of the action for extended periods if parts or maintenance personnel are in short supply.

The United States employs large numbers of maintenance personnel and transports many spare parts to war to make sure that its planes can keep operating. Other countries' planes may be less reliable because of less diligent maintenance or fewer spare parts.

Even with all of those advantages, some U.S. force planners wish to pursue aggressive modernization. As the current Vice Chairman of the Joint Chiefs of Staff, General Joseph Ralston put it in testimony before subcommittees of the House National Security Committee, "We are not looking for an equal or fair fight. If our deterrence fails and we must go to war with a future adversary, we want it to be unfair—we want the advantage to be wholly and completely on our side."[20]

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20. Joint statement of Paul G. Kaminsky and Joseph Ralston, June 27, 1996, p. 2.

Chapter Three

Administration's Plan for Tactical Aircraft

The Congressional Budget Office's analysis of the Administration's plan suggests that planned purchases should permit future Administrations to keep forces at roughly the levels called for in the Bottom-Up Review. But those plans entail two major risks, either of which could cause serious shortages: the Administration's plan assumes the services will use aircraft for unprecedented periods, and planned annual purchases may not be affordable.

Given the current modernization strategy of the Department of Defense, the availability of Joint Strike Fighters will be critical in avoiding aircraft shortfalls in the first decade of the next century.[1] The JSF purchases in the program's illustrative procurement profile are sufficient to prevent the services from experiencing substantial shortages through 2020.

Plans for the U.S. Air Force's Fighter and Attack Forces

The Air Force has 20 tactical fighter-wing equivalents (13 active and seven reserve), composed of five types of planes: F-15s, F-16s, F-117s, A-10s, and F-111s. F-111s are currently being retired, but the F-22—set to enter production in 1999—will keep the number of types of planes at five until the Joint Strike Fighter enters service. The effect of the Joint Strike Fighter on the number of types of planes depends on which planes it will replace. JSFs were originally expected to replace several Air Force aircraft including the F-16, the A-10, the F-15E, and the F-117. But the Air Force apparently now expects the strike fighter to replace only two planes: the F-16 and, eventually, the A-10.[2]

Planned Purchases

Over the next five years (from 1997 through 2001), the Air Force plans to spend about $5.9 billion purchasing 40 F-22s (see Table 3 for plans of F-22 and JSF purchases). Development funds for F-22s would add about $7 billion over the same period. The Air Force will also spend about $0.4 billion on buying a total of 12 F-15s and F-16s and $1.9 billion on JSF development during that period. Procurement funding for purchases of fighter aircraft is scheduled to grow through 2010. Over the following 10 years, annual purchases of 110 aircraft are expected to be more than double the quantities DoD expects to buy from 1997 through 2001.

1. For a review of DoD's modernization plans, see Bert H. Cooper, Jr., *Tactical Aircraft Modernization Issues for Congress* (Congressional Research Service, November 6, 1996).

2. The Air Force only recently announced that JSFs would replace the A-10. But the time of replacement has not yet been announced and the Air Force's force projections show A-10s being retained through 2015. Program office charts originally announced that JSFs would also replace longer-range attack aircraft, such as the F-15E and the F-117. But the Air Force may develop a new plane—currently termed the replacement interdiction aircraft (RIA)—for this mission or purchase a version of the F-22.

Table 3.
Administration's Plan for F/A-18E/F, F-22, and Joint Strike Fighter
(In quantities of aircraft and costs in billions of 1997 dollars)

	1996 and Before	1997	1998	1999	2000	2001	Total, 1997-2001	Funds Needed to Complete[a]	Total
F/A-18E/F									
Quantity	0	12	24	36	42	48	162	838	1,000
Costs									
RDT&E	5.0	0.4	0.2	0.1	0	0	0.7	0	5.7
Procurement	0.2	2.2	2.8	3.4	3.7	3.3	15.5	45.5	61.2
Total	5.2	2.6	3.0	3.5	3.7	3.3	16.2	45.5	66.9
F-22									
Quantity	0	0	0	4	12	24	40	398	438
Costs									
RDT&E	15.7	2.0	2.2	1.4	0.9	0.5	7.0	0	22.8
Procurement	0	0	0.1	1.0	1.8	2.9	5.9	34.1	39.9
Total	15.7	2.0	2.3	2.4	2.7	3.4	12.9	34.1	62.7
Joint Strike Fighter									
Quantity	0	0	0	0	0	0	0	2,978	2,978[b]
Costs									
RDT&E	n.a.	0.6	0.8	0.9	0.4	1.1	3.8	15.9	19.7
Procurement[c]	0	0	0	0	0	0	0	144.8	144.8
Total	n.a.	0.6	0.8	0.9	0.4	1.1	3.8	160.7	164.5
Total									
Quantity	0	12	24	40	54	72	202	4,214	4,416
Costs									
RDT&E	20.7	3.0	3.2	2.4	1.4	1.7	11.6	15.9	48.2
Procurement	0.2	2.2	2.9	4.4	5.5	6.2	21.3	224.4	245.9
Total	20.9	5.2	6.1	6.7	6.9	7.9	32.9	240.3	294.1

SOURCE: Congressional Budget Office based on Department of Defense data.

NOTE: RDT&E = research, development, test, and evaluation; n.a. = not available.

a. Costs through 2030.

b. The Department of Defense may plan to purchase additional Joint Strike Fighters for the Air Force.

c. Joint Strike Fighter procurement funding requirements as estimated by CBO from Administration flyaway goals.

Air Force Requirements for Tactical Fighter Forces

William J. Perrry, the former Secretary of Defense, expected the Air Force to keep the 20 wings of tactical fighters mentioned in the Bottom-Up Review.[3] The Congressional Budget Office estimated the number of aircraft the Air Force would require to keep tactical fighter forces at that level. Each of those 20 wings has a notional combat complement of 72 aircraft. For active units, the Air Force adds a 25-percent requirement for combat trainers to that number. It also adds a small number of planes, 6 percent, to test tactics and new systems. For reserve units, the Air Force adds a 12.5-percent requirement for trainers but no additional planes for testing. Finally, it also adds about 10 percent to the total of the combat aircraft, trainers, and test aircraft for a maintenance "float" for planes being repaired or modified. All of those factors add up to slightly less than 100 planes per wing, meaning that the Air Force would need about 2,000 planes for its 20 wings.

In 1996, the Air Force had a requirement for 10 squadrons of fighter interceptor aircraft in the Air National Guard. But by 2001 the Air Force expects that requirement to decrease to six squadrons. After adding the planes needed for those squadrons, the requirements associated with the Administration's planned force levels will total about 2,100 planes.

Fighter and Attack Aircraft Inventories

CBO also estimated how many planes the Air Force will have in inventory to meet those requirements. The Air Force will have almost 2,200 fighter and attack aircraft in its inventory at the end of 1997—about 100 more planes than it needs to equip planned forces. Even without JSF purchases, CBO found that inventories will decline slowly to about 2,100 planes by 2005—still enough to meet requirements (see Figure 2).

Under CBO's estimates, in the second decade of the 21st century, the inventory would drop off rapidly unless replacement aircraft were purchased. By 2015, the Air Force would have only about 1,750 planes. Those reductions come about largely because the F-16C/D aircraft will retire in quantity. As it is, they make up almost 60 percent of today's fleets and were bought at rates of up to 180 per year in the mid-1980s. Retirements would be so rapid during the 2010-2015 period that by 2015 the Air Force would experience shortages of more than 300 planes if it purchases no new multirole aircraft.

That outcome rests on the assumption that the service will be able to retain planes as long as it currently plans—but no longer. CBO uses the estimates of engineers to project retirements. Engineers working for aircraft manufacturers (and for DoD) test planes in development to estimate how long they can safely be flown. Based on those tests, they produce estimates of aircraft life, which DoD uses to set replacement schedules (see Appendix B for a discussion of those estimates). Current estimates forecast that today's generation of aircraft will last longer than the actual service periods of past generations of aircraft.

Force Aging

The average age of Air Force tactical forces will increase rapidly over the 1997-2020 period. Today's fighter fleet has an average age of about 10 years, slightly less than the Air Force's most recently expressed goal for fighter average age, pegged at 11 years.[4]

That goal, expressed in Air Force and DoD discussions of the capability and modernity of U.S. fighter forces, reflects a desire for an inventory with planes distributed uniformly over the age spectrum—from newly delivered planes to those approaching retirement age.[5] Such a distribution avoids block retirements that necessitate rapid replacement or large reductions in force. A truly uniform distribution in an inventory of planes with a retirement age of 20 years would result in an arithmetic average age of 10 years. (For many years, analysts in the Office of the Secretary of Defense and

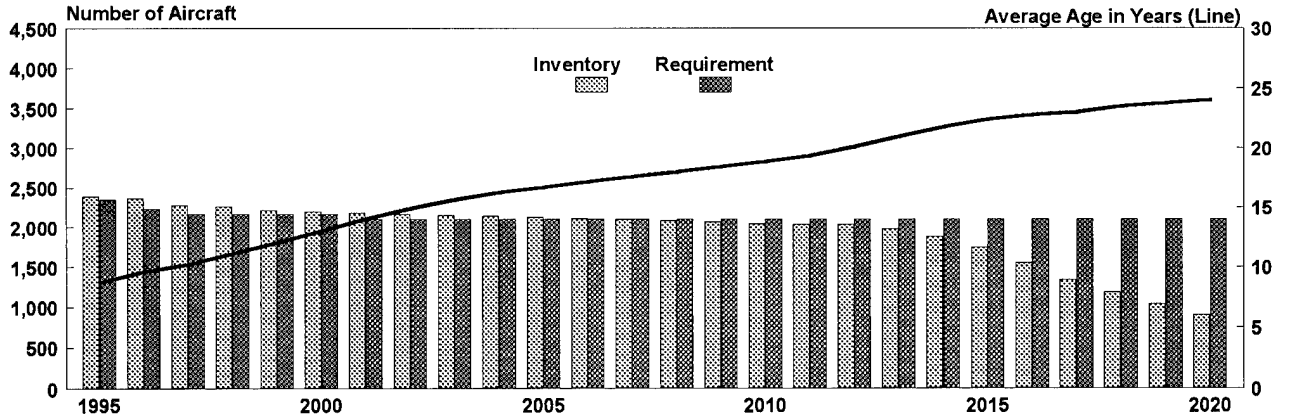
3. See Thomas E. Ricks, "Perry Says Weapons Cuts Are Unlikely As Several Reforms Produce Savings," *Wall Street Journal*, October 3, 1996, p. B5B.

4. Although engineering service lives are expressed in numbers of hours, force planners typically translate those operating periods into years—using standard annual operating service hours—to forecast force size and needs for aircraft replacement.

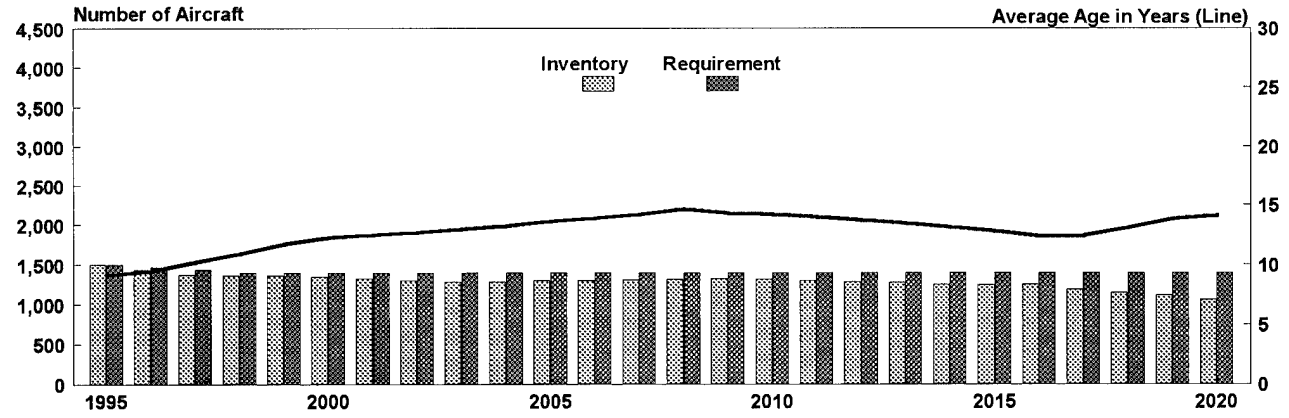
5. See, for example, Casper W. Weinberger, Secretary of Defense, *Annual Report to the Congress* (Department of Defense, 1983, 1984, and 1985).

Figure 2.
Fighter and Attack Inventories, Requirements, and Average Ages Without Purchases of Joint Strike Fighters

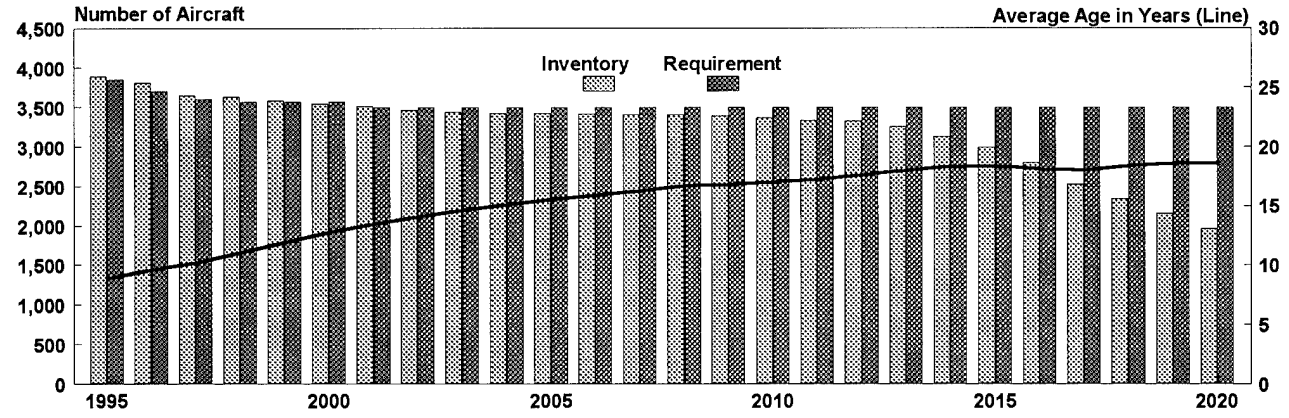
Air Force



Department of the Navy



Air Force and Department of the Navy



SOURCE: Congressional Budget Office estimates based on data from the Department of Defense.

NOTE: Aircraft retired or replaced before end of service life to fit requirements.

the services have assumed a fighter and attack aircraft service life of 20 years for most planning.)

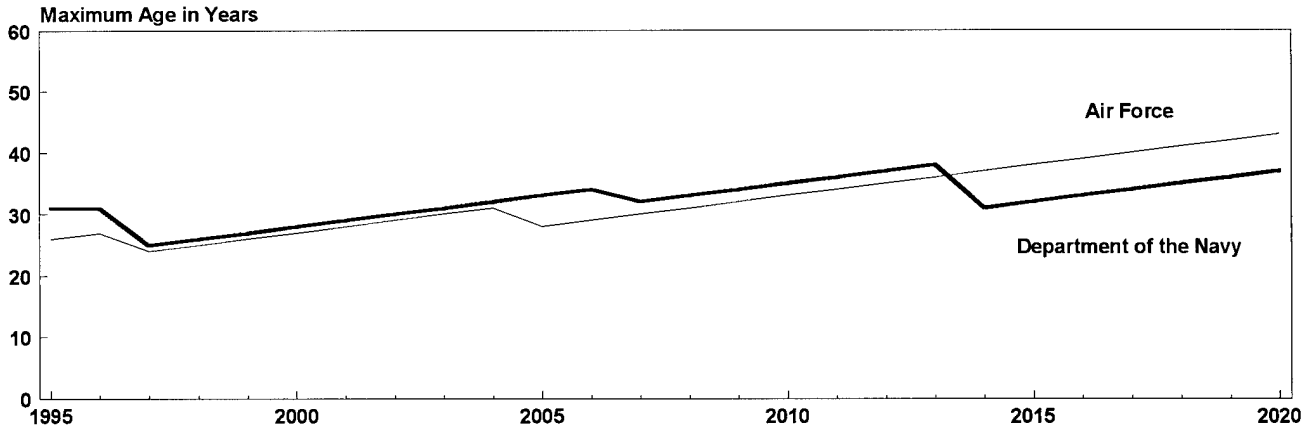
The average age of Air Force planes will grow from the 10 years of today's fleet to about 14 years by 2001. After that, the fleet will age about a half year per year through much of the remainder of the period because planned F-22 procurement rates are too low to compensate for aging in the existing fleet. The average age would reach about 19 years by 2010. Subsequently, despite block retirements of F-16s, average ages would continue to grow, reaching about 24 years by 2020. That aging occurs even if inventories were permitted to shrink to about 40 percent of their current size.

The Problems of Fleet Aging If the Joint Strike Fighter Is Delayed. If the Joint Strike Fighter program was significantly delayed, the Air Force could attempt to meet requirements by keeping planes longer. But then the average ages of fleets would of course be even higher. If the JSF program were delayed beyond 2020 and future planners attempted to keep a 20-wing force, the Air Force's fleet would reach about 25 years of age by 2017.

The service would also need to retain more than half its fleet beyond currently planned retirement ages to keep inventory levels that high. As a result, the service would need to operate some very old aircraft. Indeed, by 2020 the oldest Air Force fighter aircraft would be more than 40 years of age (see Figure 3). Consequently, the Air Force would have to operate fighters and attack aircraft about twice as long as it has historically. (See Appendix B for a discussion of how the Air Force and Navy estimate aircraft service lives and about the reliability of those estimates.)

The Implications of an Aging Fleet. What are the ramifications of an older fleet? Is it reasonable to assume that fighters will operate longer than they have in the past? Although there are no simple answers to those questions, the services have raised several issues in the past when discussing measures of fleet aging. During the Cold War, DoD used measures such as average age as proxies for technological obsolescence, based on the fear that enemy forces will field systems with capabilities that so exceed those of U.S. systems as to make them obsolete. The services also express concerns about older fleets costing more to maintain and experiencing higher accident rates. They also worry about whether vendors will be available to provide parts for modifications. Perhaps of most concern is the issue that an older fleet leaves planners less flexibility to react to unforeseen delays or cuts in procurement (since the fleet is already so old it may be difficult to extend service lives even longer).

Figure 3.
Maximum Ages of Air Force and Department of the Navy Fighter and Attack Aircraft



SOURCE: Congressional Budget Office estimates using data from the Department of Defense.

NOTE: Assumes aircraft are kept to meet force requirements. Assumes Joint Strike Fighter purchases are delayed beyond 2020.

Technological obsolescence was a major concern during the Cold War, when intelligence estimates predicted that the former Soviet Union would embark on an aggressive program to modernize its fighter planes.[6] That concern is less important today. Most analysts would argue that potential U.S. foes in a post Cold-War world lack the resources to develop planes with capabilities that exceed those of current U.S. fighters for the foreseeable future.

Nonetheless, as the earlier discussion of the threat indicates, the services are suggesting that potential U.S. opponents will modernize their aircraft and their air-defense systems.

The idea that aircraft would experience more operating problems as they age seems intuitively correct: after all, the family car usually costs more to maintain as it gets older and is more likely to break down on the freeway. Not surprisingly, though, the services tend to maintain aircraft more intensively than all but the most diligent car owner. Consequently, aging aircraft fleets may result in fewer operational problems than aging household vehicles.

Resolving the issue of whether aging trends for fighter aircraft will produce operating problems is difficult. The Air Force has not been able to document operational problems linked to aging. Lack of documentation springs in part from lack of data. The services have never kept fighter planes beyond about 30 years, and in most cases fighter aircraft have retired at 20 years or less. At that point, they have operated perhaps 4,000 hours to 6,000 hours—about half the operating periods of the oldest aircraft in current plans. Therefore, some caution may be in order when discussing the feasibility of operating planes as long as the services may need to simply because they have never done it before.

Conversely, the services have operated other types of aircraft—including short-range transport planes and strategic bombers—for much longer periods. Commercial airliners also operate for 90,000 hours or more, many more flight hours than even the long-lived B-52 bomber. But those planes fly such different flight profiles from fighters that they probably are not good proxies for them.

If aircraft experience structural fatigue earlier than expected, DoD can probably pay for modifications that extend service lives. The services recently have chosen to retire planes rather than modify them, since force structure is being reduced anyway and modifications can be costly. One example is the F-16A/B model that the Air Force is currently phasing out of its fleet. Lockheed Corporation estimated that a program to extend the service life of the F-16 would have cost about half the original purchase price of the plane to get a 50 percent extension in life (the modification would have also upgraded systems to permit the F-16s to operate with newer Air Force aircraft). Still, if a large portion of the fleet is very old and experiences structural problems, the services may be compelled to pay for modifications. If they have to pay to reestablish production lines for parts, such modification could be costly.

Plans for the Department of the Navy's Fighter and Attack Forces

Fighter and attack aircraft in the Navy and Marine Corps (that together make up the Department of the Navy) are fielded in 11 air wings for the Navy's 12 aircraft carriers (the 12th carrier is typically not available for operation and does not need a wing, according to recent Navy arguments). They are also found in four Marine Corps air wings, some of which operate off the 11 large amphibious ships that transport Marine forces.

Requirements for Tactical Fighter and Attack Forces

The naval aircraft inventories that support those forces consist of four different types of fighter and attack aircraft: A-6 medium range bombers; AV-8 short takeoff vertical landing aircraft for the Marine Corps; F/A-18 fighter bombers; and F-14 fighters. In 1995, the Department of the Navy fighter and attack aircraft requirement to support those forces totaled about 1,500 planes. By 1998, that requirement will decline to about

6. The department may have overestimated the speed of Soviet modernization during the Cold War.

1,400 as the Navy decreases the number of aircraft in each carrier wing.

Planned Purchases

Over the next five years (from 1997 through 2001), the Department of the Navy plans to spend about $15.5 billion on purchasing 162 F/A-18E/F aircraft. It will also buy six F/A-18C/Ds. Development funds for the Navy Department's fighters would add about $2.7 billion over the same period.

As with the Air Force, purchases and procurement funding for Navy aircraft are scheduled to grow over the next decade. They will peak by 2009, when the Department of the Navy expects to begin purchasing 120 planes per year, a sizeable increase over near-term purchases. Navy purchases will continue at those levels through 2014, when F/A-18E/F purchases are scheduled to taper off.

Fighter and Attack Aircraft Inventories If the Joint Strike Fighter Is Delayed

Although CBO assumes that the Department of the Navy will purchase 690 F/A-18E/F aircraft during the 1997-2010 period, the department would still experience substantial shortfalls if no JSFs were procured. The Navy will experience modest shortfalls beginning around 1998, after the A-6 retires. Shortages would remain at manageable levels through 2012. They would grow in the second decade of the 21st century and by 2020, the Navy would have only about three-quarters the planes it needs for itself and the Marine Corps.

Aircraft and Aging

The Navy's fleet of aircraft is currently about the same age, on average, as that of the Air Force. But purchasing the F/A-18E/F and retiring the A-6 will prevent the average age of the fleet from increasing much during the next two decades. Even if the Navy keeps planes longer to avoid large shortages, average fleet age would not exceed 15 years until almost 2020. Moreover, using such a strategy, the Navy can reduce shortages to less than 100 planes through most of the period of CBO's analysis.

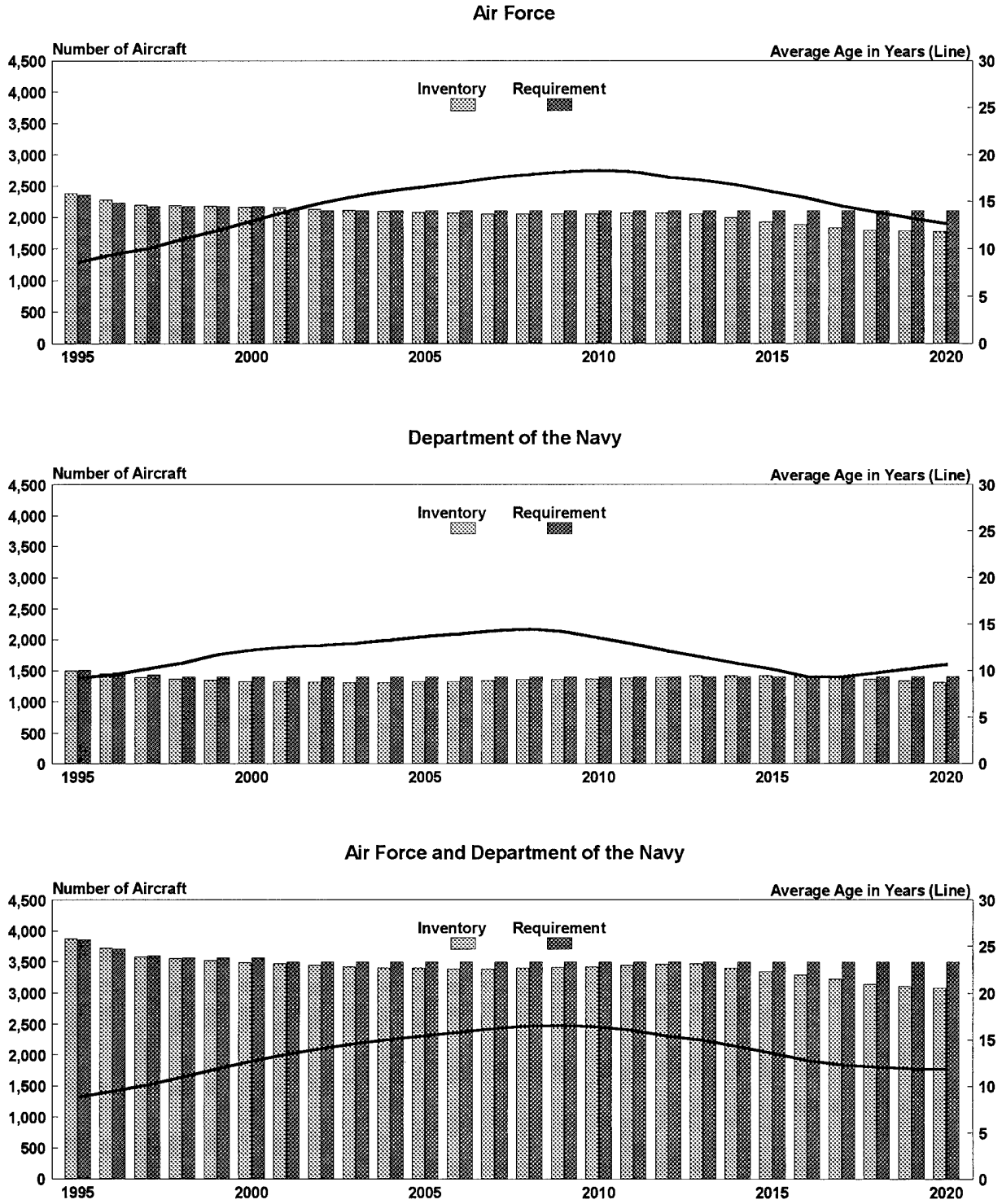
The Navy appears to—and may indeed—have less of an aging problem than does the Air Force. However, in the past, the Navy has held goals for average age that are lower than those of the Air Force. In the early 1980s, for instance, the service reported a desire to keep its fleet at an average age of about 7.5 years. According to the Navy, those lower goals reflected the more austere operating environment that its aircraft actually face.

Procuring the Joint Strike Fighter Decreases Shortfalls

The development effort for the Joint Strike Fighter is aimed at getting planes into production before block retirements create acute shortages. The planned production schedule for the JSF would accomplish that goal for both the Air Force and the Navy through much of the period of analysis, though quantities are not quite sufficient to completely avoid shortages. Shortages in the Air Force would not begin until 2013 (see Figure 4). In the Department of the Navy, they would begin several years later. Significant shortages would then grow for both services through 2020. Shortages can, however, be almost completely avoided if DoD retains planes beyond their planned retirement ages.

JSF deliveries, which do not start until 2007, will not help the Department of the Navy avoid its near-term shortages. The Navy—bedeviled by aircraft shortfalls over the last two decades—is attempting to solve its shortages by altering the size and composition of its air wings to decrease its aircraft requirements. Four squadrons of Marine Corps F/A-18 fighter and attack aircraft will provide planes for carrier air wings left short of U.S. Navy aircraft. The Congressional Budget Office has included the requirement associated with those four squadrons since neither the Navy nor the Marine Corps wishes to acknowledge eliminating that force structure. Though current plans for procuring the JSF should enable the Department of the Navy to meet its requirements around 2013 to 2016, the Navy might experience modest shortfalls in the period from 2017 onward.

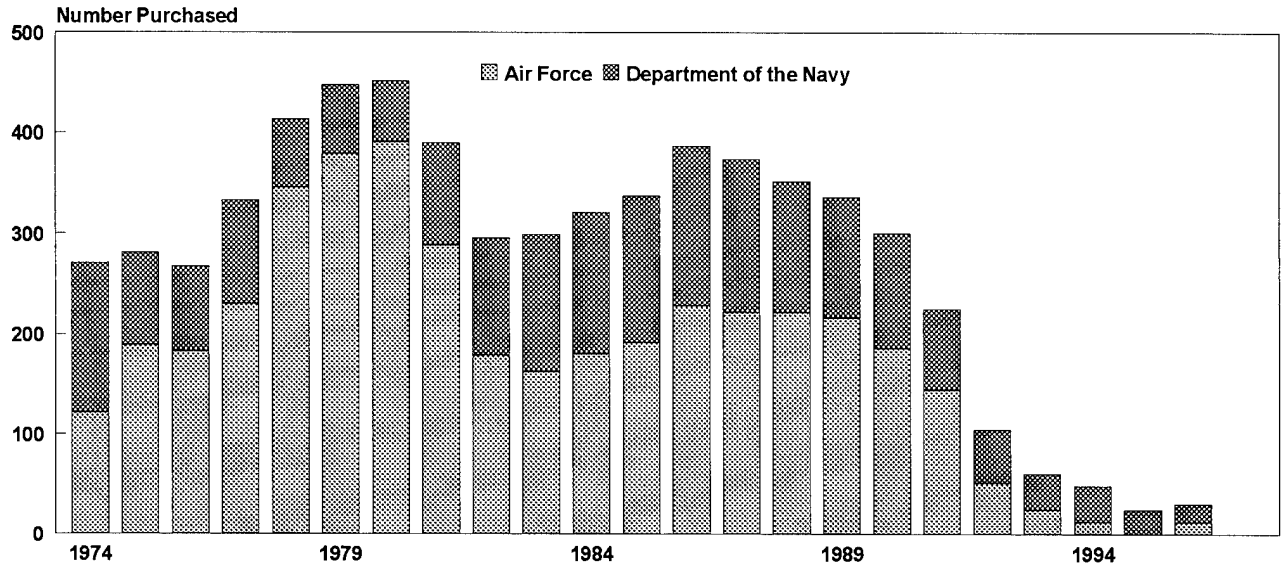
Figure 4.
Fighter and Attack Aircraft Inventories, Requirements, and Average Ages with Purchases of Joint Strike Fighters



SOURCE: Congressional Budget Office estimates based on data from the Department of Defense.

NOTE: Aircraft retired or replaced before end of service life to fit requirements.

Figure 5.
Previous Fighter and Attack Aircraft Purchases



SOURCE: Congressional Budget Office based on data from the Department of Defense.

How Affordable Are Fighter Aircraft?

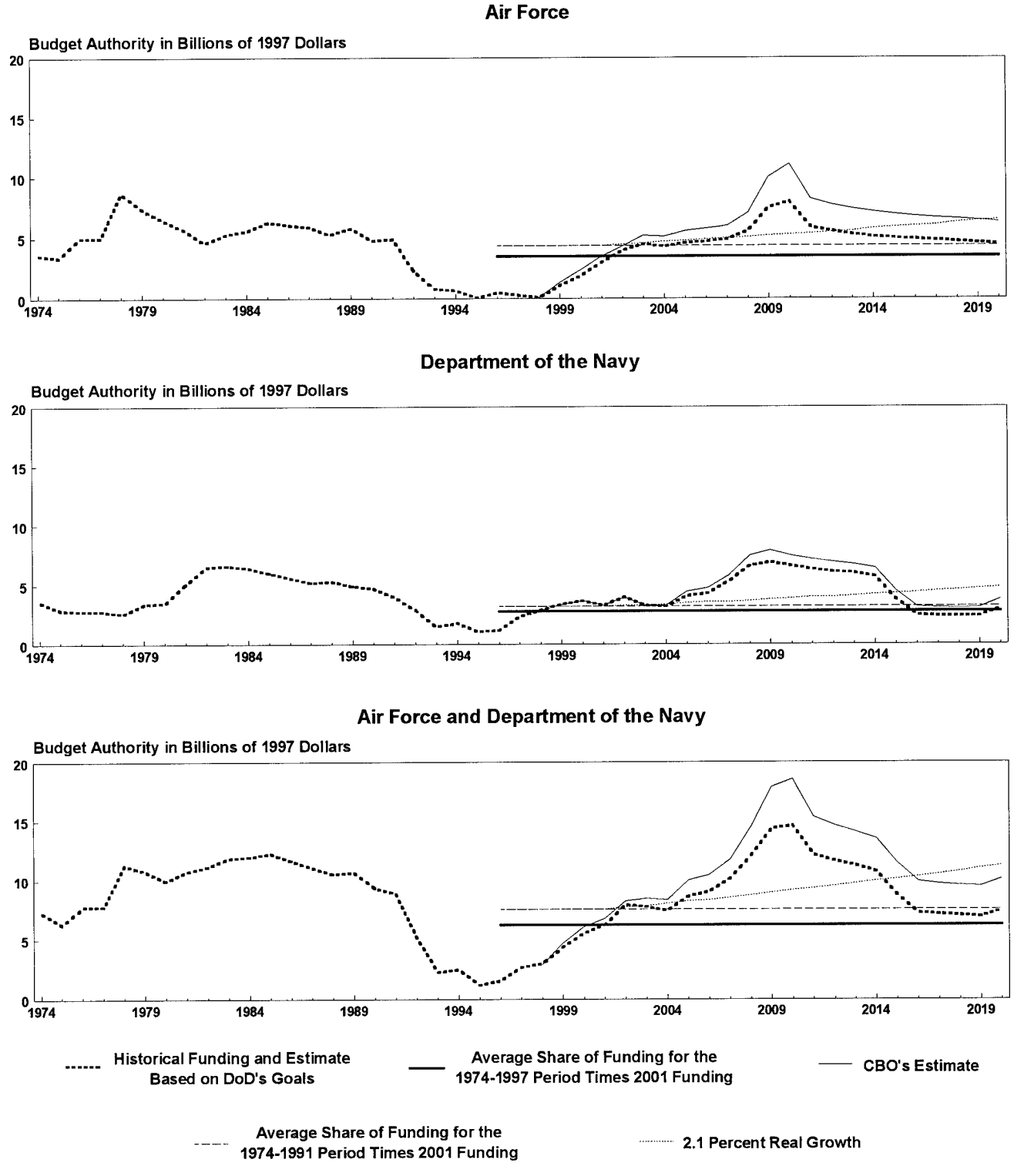
If the JSF program is able to purchase planes at rates equal to those of its illustrative schedule, the services should be able to keep up force levels. But can DoD afford to purchase the JSF on the assumed schedule? In recent years, the Department of Defense has purchased few fighter and attack aircraft compared with the number it bought previously (see Figure 5). Procurement—measured either by the quantities of planes purchased or the funds to buy them—declined from the mid-1980s through the mid-1990s. In 1995, the Air Force purchased no tactical fighters and the Navy bought only 24. That "procurement holiday" was made possible by the rapid drawdown of forces at the end of the Cold War. Large excess stocks of fighters meant that the services could forgo purchases and live off planes purchased during the 1970s and 1980s. But DoD decisionmakers suggest that the procurement holiday is already ending, as force drawdowns are completed and large-scale retirements bring inventories more in line with requirements.[7]

Allocating More Money to Fighter and Attack Aircraft

The Administration also plans to allocate more money to fighter aircraft in the future. By 2002, new production programs for fighter aircraft—the F-22 for the Air Force and the F/A-18E/F for the Navy—will bring the Administration's planned funding for fighters up to and above the share of the defense budget that fighters have enjoyed on average over the past 22 years (see Figure 6). CBO estimates that the Air Force and Navy would need to spend an average of $9.6 billion annually over the 2002-2020 period to purchase the planned quantities of the two aircraft plus the JSF. If the prices of those planes turn out to be higher than DoD expects—a likely outcome—DoD would need to spend an average of $11.9 billion each year over the same period.

7. See, for example, Office of Assistant Secretary of Defense, "Department of Defense Budget Request for Fiscal Year 1997" (press release, Washington, D.C., March 4, 1996), p. 3.

Figure 6.
Historical and Projected Funding for Fighter and Attack Aircraft (By fiscal year)



SOURCE: Congressional Budget Office.

Those numbers exceed the amount of money that DoD would have if it was to spend the same share of future budgets on fighter aircraft as it has spent in the past. During the 1974-1997 period, the Air Force allocated an average of about 4.6 percent of its annual budgets to new fighter procurement and the Navy allocated about 3.6 percent. CBO applied those percentages to the service funding at the end of the Administration's defense plan for future years to determine how funding requirements might compare with past funding shares. If the defense budget remains constant in real terms after 2001, and if DoD expends on fighter purchases the same share of future service budgets as it has in the past, funding could total $6.3 billion annually (in 1997 dollars). Thus, required funding might exceed available funding by about 50 percent to almost 90 percent, depending on which pricing assumption proves to be correct.

DoD could devote more funding to tactical aircraft if it chooses to do so. A number of other mission areas have been deemphasized—areas that fighters would have competed with for funding in the past. For example, the historical-shares approach implicitly assumes that DoD will continue to spend a large portion of its funding on strategic programs. If the deemphasis of strategic missions results in disproportionate cuts in spending on purchases of bombers, ballistic missiles, and other strategic systems over the long term, funding for fighter aircraft could rise to absorb some of the slack. But DoD would need to allocate sizable increases in fighter shares to purchase its current plans.

Some DoD personnel argue that tactical fighters will be able to absorb a larger share of the funding usually devoted to investment in aircraft (that is, development and procurement).[8] General John Shalikashvili, Chairman of the Joint Chiefs of Staff, argued that increasing the Defense Department's total annual procurement spending to at least $60 billion—roughly increasing funding from today's levels by about 50 percent—would be needed to meet procurement requirements. Paul Kaminski, Under Secretary of Defense for Acquisition, indicated in recent testimony that investment in tactical fighters would represent a much larger share of total aircraft investment but that total aircraft funding would not be out of line with past experience because significant funds would not be needed in the future for airlifters or bombers. Finally, General Joseph Ralston, Vice Chairman of the Joint Chiefs of Staff, argued that aircraft investment is cyclical and suggested that the first decade of the 21st century would be the TACAIR (tactical aircraft) decade—in other words, a decade of heightened expenditures on tactical fighters.

If DoD's budget was to rise during this period, small fractions of the total budget, devoted exclusively to tactical fighter purchases, could pay for any shortfalls. But if, as happened during the early 1980s, tactical fighters did not gain a significant share of budget increases, service budgets would need to grow by large percentages to pay for fighter funding. If fighters keep their historical shares, a real increase of more than 2.1 percent in total defense budget authority would be needed even if aircraft prices do not rise above DoD's expectations.

Increased Funding May Prove Unlikely

Assuming that significantly larger amounts will be available for fighters might be optimistic. The Administration does plan on increasing procurement spending in its current budget plans. Those plans call for total spending on procurement to grow to about $60 billion in current dollars—or about $55 billion in 1997 dollars. However, that growth is to take place over the five-year period from 1997 through 2001 instead of by 1998 as Chairman Shalikashvili was apparently recommending. But even at that level, the share of DoD's budget for procurement funding is 22 percent in 2001, which is lower than its average share during the past 22 years by about 3 percentage points.

CBO's estimate of the amount available for fighter and attack procurement implicitly assumes that procurement retains the higher historical average because it is based on an average of the shares devoted to purchases of tactical fighters over a long period (from 1974 to 1997). Yet, during that period, procurement funding averaged 25 percent of the defense budget. If procurement was reduced even to the peak funding share in the Administration's plans—22 percent—and fighter aircraft received their historical share of that

8. Joint statement of Paul Kaminski, Under Secretary of Defense for Acquisition and Technology and General Joseph W. Ralston, Vice Chairman of the Joint Chiefs of Staff, before the Subcommittees on Military Research and Development and on Procurement of the House Committee on National Security, June 27, 1996.

lower level, only about $5.5 billion might be available annually for procurement—or $0.8 billion less than in CBO's baseline assumption.

Some analysts would argue that even making the increases in procurement funding that the Administration plans may be difficult. Assuming the defense budget remains constant in real terms after 2001, such increases must come at the expense of other appropriation categories, such as operation and maintenance and military personnel.[9] Making large cuts without harming the readiness of DoD's forces for war involves making changes in DoD's infrastructure—for example, closing bases, or consolidating, eliminating, and finding more efficient ways of providing support functions. All of those changes have proven challenging in the past and may prove even more challenging in the future since the least painful cuts may have already been made.

DoD's forecasts, such as those presented by Under Secretary Kaminski in his June 1996 testimony before the House National Security Committee, also suggest that aircraft investment (development and procurement) over the 2002-2013 period would not rise significantly above historical shares, despite large increases in tactical fighter funding.[10] The basis for DoD's argument—that the lion's share of aircraft investment spending for the next decade and a half should go toward procuring fighters—seems to be that few other aircraft will be procured and most aircraft development will be halted. Such an acquisition strategy probably would mean that DoD would need to eliminate missions for which no aircraft are developed or procured for that long a period. DoD has yet to announce formally that it intends to eliminate the mission areas that receive little funding.

Some analysts might argue that DoD's estimates should also contain funds for developing the next generation of fighter aircraft, since funding for developing fighter aircraft has never dropped so low before. It is difficult to imagine what aircraft the United States will need 30 years from now. Therefore, it is tempting to leave the next generation of fighters out of calculations for development funding 10 or 15 years from now, which is one reason that CBO's analysis focuses on procurement funds.

Other factors suggest that the amount of funding accorded in CBO's historical shares estimate could be too high. For example, CBO assumes that DoD's budget rises with inflation during the 2002-2020 period. Both the Congress's and the Administration's plans for balancing the budget assume that DoD will need to absorb some inflation in the near term. Yet cuts for inflation could feasibly continue beyond 2002. The Administration has not provided estimates of its plans for defense for the period beyond 2002. But if such cuts materialize and are proportionately distributed, funding for fighters could be lower than the numbers included in CBO projections.

At least one industry forecast, by the Electronics Industry Association (EIA), takes as its most likely defense budget a path that assumes real declines beyond 2000.[11] EIA assumes spending for the Department of Defense budget would drop from $234 billion in 2002 (about $6 billion less than EIA's estimate of what the Department of Defense's share of national defense spending could be in 2002 based on the Congress's current plans) to $231 billion in 2003 and 2004 (all estimates are in 1997 dollars). The EIA forecast dips again to $230 billion in 2005 before rising slightly to $232 billion in 2006.

Trends in other portions of the budget may suggest increasing pressures on defense spending, particularly after 2010 when the baby-boom generation begins reaching retirement age. A recent CBO publication projected trends in federal revenues and budgets over the 1995-2050 period.[12] The study cites Social Security Administration statistics predicting that the number of people 65 and older will double during the 1990-

9. Congressional Budget Office, *Trends in Military Operation and Maintenance Spending* (forthcoming), will suggest that reducing operation and maintenance spending below current levels could be difficult.

10. Joint Statement of Paul Kaminski and Joseph Ralston, June 27, 1996.

11. Electronic Industries Association, *EIA Ten-Year Forecast of Defense, NASA and Related Markets Electronic Opportunities (FY 1997-2006)* (Washington, D.C.: Electronic Industries Association, October 1996). These numbers reflect the funding for the programs in the Department of Defense, but they exclude funding for National Security in other departments.

12. Congressional Budget Office, *The Economic and Budget Outlook: Fiscal Years 1997-2006* (May 1996), pp. 69-95. The discussion in this section is largely excerpted from Chapter 4 of that study on long-term budgets. It provides an explanation of those trends, their implications, and possible solutions. The chapter also details many of the assumptions associated with CBO's projections.

2030 period, whereas the number of working-age people will increase by only a quarter. The study presents projections for deficits and public debt based on a variety of assumptions about a number of factors that influence the economy.

All of CBO's projections suggest that, unless policymakers provide remedies, those retiring baby-boomers will cause spending on entitlement programs to grow rapidly and tax revenues to decrease because of lost earnings. Largely as a result of those demographic trends, CBO projected that the debt held by the public could increase from the level in 1998 of about half of the gross domestic product (GDP) to about 80 percent of GDP by 2015 and over 100 percent by 2020. The United States only once let its public debt exceed 100 percent of GDP, and that was for a brief period during World War II.

Increases in domestic rather than defense spending cause the debt to burgeon in CBO's projections. Nonetheless, defense spending could easily be targeted as a part of deficit reductions packages proposed to head off the economic crisis from sustaining this level of debt. Moreover, any large declines in future defense budgets could substantially decrease available spending for fighter aircraft.

Even if future defense budgets remain constant, fighters will compete for funds with a number of other weapons. Other services have also experienced procurement holidays and will want to begin purchasing weapons in larger quantities. The Army plans an extensive modernization program for its helicopter fleet and, in the 2002-2020 period, the Navy plans to buy roughly double the number of ships that appear in its near-term budgets. In addition, DoD has added theater-level and national missile defenses to its force requirements. Those high-priority, costly programs might well draw resources from fighter aircraft.

How Two Estimates of the Costs of Fighter and Attack Aircraft Plans Compare with Historical Spending Trends

How much fighters still in development—such as the JSF, the F-22, and the F/A-18E/F—will cost is most uncertain. The Department of Defense has its own goals, and one of CBO's estimates of total costs focuses on them. But DoD has often underestimated future aircraft prices in the past. CBO has also developed an alternative estimate that assumes fighter prices follow historical relationships between cost and weight and performance. That estimate yields a larger sum.

Funding Requirements for the Department of the Navy's Planes Using DoD's Price Goals. The Department of the Navy requires less money each year on average for tactical aircraft during the 2002-2020 period than the Air Force, but it may have more of a problem meeting its funding requirements. During that period, the Congressional Budget Office estimates that the Navy's funding requirements would average about $4.5 billion. If the Navy's budget experiences no real increases or decreases beyond 2001, the Navy would spend about 5.7 percent of its annual budget on fighter and attack aircraft acquisition.

Navy funding would also experience a bow wave during the first decade beyond current plans. Funding during the 2002-2015 period averages $5.2 billion and would absorb about 6.6 percent of a constant Navy budget during that period. In fact, even during the 1974-1988 period—a time when large numbers of tactical fighters were bought—only about 4.2 percent of the Navy budget was spent on those purchases, about 60 percent of the funding share Navy fighter and attack aircraft would need over the 2002-2015 period even if price goals were met. Peak funding in 2009 would require spending almost 9 percent of a constant service budget—or about 50 percent higher than the highest share of funding the Navy has given fighter and attack aircraft since 1974.

Furthermore, CBO's analysis suggests that purchases of fighter and attack aircraft could have heavy competition for the Navy's funding during the next several decades. Other budget pressures could make it difficult to allocate so much additional funding to them. The Navy will need to purchase a large number of ships during that period. The Navy has given high priority to its ship purchases in past years. Indeed, some analysts might argue that the Navy's enduring aircraft shortages of the 1980s resulted from the high priority the service accorded ship purchases.

If the Navy does not accord higher priority to fighter aircraft, such a funding mismatch might mean the service would be unable to purchase the number of JSFs included in the JSF program's illustrative plans (cuts in planned quantities also cause costs to rise, which can result in larger cuts). The potential shortfalls in Navy fighter funding could exacerbate any concerns about the Navy's dropping out of the JSF program. If the Navy was to drop out of the Joint Strike Fighter program, it would only worsen any aircraft shortages it has during this period. The flexibility to deal with bigger shortages of aircraft would be limited since the Navy has already reduced the number of planes in each of its carrier wings to deal with shortages.

Costs for Air Force Planes Using DoD Price Goals. Estimates of aircraft funding for the Air Force suggest slightly less of a problem during the period from 2002 through 2020, at least if DoD was to meet its price goals. However, the Air Force's peak-year funding indicates that the service will be unable to purchase both the JSF and F-22 at the currently planned rates. The Air Force's funding for fighter aircraft—with a slow increase in the number of F-22s purchased—would reach $4 billion by 2002 and peak at almost $8 billion in 2010 when JSF purchases overlap with F-22 procurement. Air Force funding requirements would average $5.2 billion over the 2002-2020 period. Those levels are higher than the amount of the share of funding the Air Force has devoted to fighter aircraft in its past by about 50 percent.

Why might the Air Force be more able to provide funding at those levels when the Navy might find them unaffordable? The main reason is that the Navy—having more demands on its funding than the Air Force and smaller tactical air fleets—has historically spent less of its budget on aircraft than the Air Force. But also the Air Force has made an effort to develop a phased procurement schedule that avoids large overlaps in aircraft purchases. That strategy means that the Air Force plans to begin JSF procurement when funding for the F-22 is tapering off.

The Navy's plans do not appear to reflect a similar strategy since its tactical fighter purchases overlap for a longer period. For example, the service plans to purchase JSFs for the Navy and the Marine Corps at the same time that it is purchasing the F/A-18E/F during the 11-year period from 2005 to 2015. Some analysts would argue that the simultaneous purchases in the Department of the Navy's plan are illusory since the service could easily choose to purchase only one of those planes. But current pricing for both programs depends on the production quantities in the plan being realized.

As a result of its attempt to avoid having its purchases overlap during past periods, the Air Force has devoted a large share of its budgets to funding fighter aircraft. For example, during the 1974-1988 period, the Air Force allocated about 6 percent of its budget to purchases of fighter aircraft compared with the approximate share of 2 percent of its annual budget that it provided during the 1989-1997 period. Moreover, the Air Force's peak historical funding share for fighter aircraft since 1974—about 11.5 percent in 1978—is almost double the Navy's and higher than the 10.6 percent the service would need in 2010 under current plans.

Finally, the Navy and Marine Corps will probably pay more for each of their Joint Strike Fighters, though they will buy them in smaller annual quantities. The program goals for the Navy's JSF—about $31 million to $38 million (flyaway costs in 1994 dollars)—suggest that it could have a procurement unit cost of about $61 million compared with $45 million for the Air Force version since the Navy has greater mission requirements. The Navy also has in the past purchased more expensive aircraft than the Air Force. For example, prices of early models of the F/A-18—the Navy's lower-cost aircraft—were twice as much as their Air Force counterpart, the F-16. The Marine Corps' version with its challenging short takeoff vertical landing flight profile might cost about $54 million, modestly more than the price the Air Force might expect to pay for its plane. Price increases for the Marine Corps' requirement for vertical flight might be offset, at least in part by the service's willingness to trade off improvements in capability such as accepting a less stealthy design.

Congressional Budget Office's Estimates of Fighter Prices

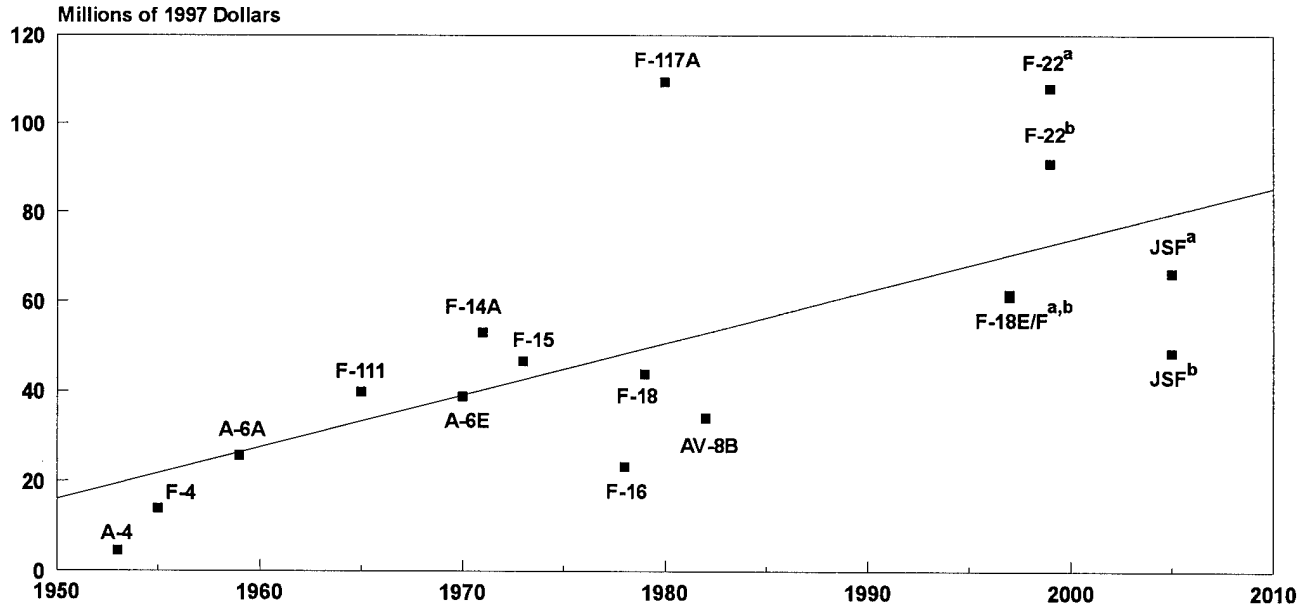
CBO also estimated future fighter costs based on so-called "cost-estimating relationships" (see Appendix C for a discussion of estimating fighter prices). Those equations measure historical relationships between price and aircraft weight and performance. CBO's anal-

ysis indicates that future fighters could cost considerably more than DoD price goals would imply. The Joint Strike Fighter could have a procurement unit cost of $63 million for the Air Force version, $81 million for the Navy version, and $68 million for the version of the plane that the Marine Corps might purchase (see Table 2 in Chapter 1). CBO also produced an alternate estimate for the F-22 that shows a possible unit procurement cost of about $108 million, about 19 percent higher than the Administration's estimate. According to CBO's analysis, the F/A-18E/F's current estimate is in line with past patterns. Consequently, CBO kept the same cost for the fighter in both estimates.

Pricing DoD's Plans with the Congressional Budget Office Estimates. If prices rise to CBO's projected higher levels, average annual DoD funding requirements for fighter aircraft over the 2002-2020 period would rise to $11.9 billion, roughly 20 percent more than the estimate based on DoD's goals.

The Navy's average annual funding requirements from 2002 through 2020 would rise to $5.1 billion—about 14 percent more than the Administration's pricing assumptions and more than double the previous shares. Moreover, in the CBO estimate the Air Force—which had smaller funding shortfalls under the estimate that assumes price goals are met—develops a bigger funding shortfall than the Navy. The Air Force would need almost $7 billion a year during the 2002-2020 period. Amounts required for the two services in 2009 and 2010—the peak funding years for the Navy and Air Force, respectively—come to $8 billion for the Navy and more than $11 billion for the Air Force. Paying those sums would require the Navy to almost triple the share it devotes to fighter purchases. The Air Force

Figure 7.
Unit Procurement Costs for Fighter and Attack Aircraft



SOURCE: Congressional Budget Office.

NOTE: The line is a linear regression of the historical aircraft cost.

a. CBO estimates.

b. Administration estimates.

Table 4.
Summary of Technological Developments in Tactical Aircraft

Design Component	1950s	1960s	1970s	1980s	1990s	2000s
			Technology			
Airframe	Aluminum; steel	Titanium; some composites	10 percent to 20 percent of structural weight composites	10 percent to 20 percent of structural weight composites	Metal matrix composites	Major use of composites in structure; integrated mechanical systems (electrical/hydraulic)
Avionics	Analog gauges; vacuum tubes	Analog gauges; transistors; some avionics integration	Large-scale integrated circuits; hard-wired digital signal processing; multifunction displays; head-up display	Programmable signal processors; very large-scale integrated circuits; crew-avionics interactions	Fully integrated avionics; bus/module-based architecture; full helmet display; very high-speed circuits	Greater integration of avionics functions; common antennas and receivers; reduction in number of components
Propulsion	Moderately high-turbine temperatures; cooled turbine; titanium begins to replace aluminum	Superalloy materials; high-temperature turbine; improved cooling techniques	High thrust to weight; high-temperature materials; composite materials	Turbine inlet temperatures ~2,550°F; metal single crystal blades; microprocessors for better control	Turbine inlet temperatures ~2,850°F; non-metal parts; integration of aircraft and engine controls	Turbine inlet temperatures ~3,400°F; exotic cooling; afterburners not needed for supercruise; reduced signatures
Signature	No stealth	No stealth	No stealth	LO; VLO	LO; VLO	LO; VLO
			Aircraft That Enter Fleet During Period[a]			
Aircraft Model	A-4A-C F-4A, A-6A	A-4E/F F-4B/J F-4C-E F-111	F-15A-D F/A-18A/B A-6E, F-14A	AV-8B F-15E F-16C/D F-117A F/A-18C/D	F/A-18E/F	F-22, JSF

SOURCE: Congressional Budget Office based on data from Bruce R. Harmon and others, *Military Tactical Aircraft Development Costs* (Alexandria, Virginia: Institute for Defense Analyses, September 1988).

NOTES: LO = low observable; VLO = very low observable. Not all aircraft incorporate all technologies.

a. Not all aircraft incorporate all technologies.

would need to more than triple its share of funding for fighter aircraft from average shares in the past.

Which Estimates Are More Realistic?

If the number of purchases of tactical aircraft depends so much on assumptions about pricing, which prices are more realistic? Unfortunately, fighter prices could easily be higher than those associated with the Administration's goals, particularly for the Joint Strike Fighter. Historical cost-estimating relationships suggest that weight, performance, and costs are closely tied.

Fighter prices grow from one generation to the next as DoD introduces more advanced technologies and capabilities into its tactical aircraft (those data underlie cost-estimating relationships). Since the 1950s, fighter prices have doubled or tripled from one generation to the next as those technologies have been introduced. (See Figure 7 on page 37 for historical price trends for fighter and attack aircraft and Table 4 for a summary of developments in technology that might have contributed to price increases.)

Program goals for JSF prices assume that the program will not experience as much price growth as those trends might suggest, at least for the Navy and Marine Corps versions. DoD's price goal for the Air Force version is a flyaway cost of about $28 million in 1994 dollars. CBO estimates that amount would correspond to a procurement unit cost of about $45 million. That price is consistent with previous price growth, but only if one looks at the pattern in the least sophisticated aircraft. That unit price for procurement is about twice the average price of the JSF's predecessor, the F-16, which in turn cost about twice as much as its predecessor, the F-4.

The price goals for the Navy and Marine Corps versions are in surprisingly low, even when compared with the trend in less capable planes. They represent increases of only about 60 percent above the purchase price of the A-6E and the AV-8B Harrier, respectively, when those planes cost almost twice the price of their predecessors.[13] (That disparity may also suggest that the Navy's costs might rise significantly in relation to the goal for the Air Force version after the source is selected.) Even the Navy's F/A-18A to D models had a price tag that was about twice the F-4s, their fighter predecessor.

The services have also fielded a number of other planes that represented more than a doubling in price during each decade. True, those planes—including the Navy's F-14 and the Air Force's premier fighter, the F-15—achieved more significant improvements in capability than DoD may be expecting from the JSF. Nonetheless, look at the total picture. If all fighter and attack aircraft purchased by the services were taken into account, the JSF price goals, including those for the Air Force, would fall well below the average. As a result, all JSF prices might increase, perhaps to the level of CBO's estimate or higher if the program delivers substantial improvements in capability.

The Joint Strike Fighter program office argues that past experience—such as that represented in the cost-estimating relationships and reflected in generational price trends—is not relevant to the JSF. Yet, as discussed in the next chapter, aircraft prices are to receive more emphasis in the JSF program than they received in earlier development efforts. The program manager's position is that any improvements in capability need to earn their way into the program. He also argues that future managers, confronted with traditional trade-offs between controlling cost and enhancing capability, will accord higher priority to controlling cost than the managers of earlier programs.

Nonetheless, the JSF program is promising substantial increases in capability over current aircraft, particularly in the realm of stealth. However, some analysts argue that stealth has definite cost penalties. The F-22 and F-117A, two stealthy planes, have prices that are significantly higher than other more conventional fighter and attack aircraft. Low production quantities and rates account for some of the difference in price. But the requirements for stealth performance also drive up costs. Whether DoD's price goals for the JSF fully account for additional costs related to stealth technologies remains unclear.

13. Selecting the "correct" predecessor for the A-6 is difficult. Some analysts argue that the A-3, a carrier-based strategic bomber is the appropriate predecessor. A-6s cost almost 90 percent more than the A-3. Other analysts argue that the A-1 which emphasized a nonnuclear mission is the plane that is truly the A-6's predecessor. A-6s cost more than 10 times the price of the A-1.

If the performance of the Joint Strike Fighter has to be so diminished to meet price goals that it barely exceeds that of the current generation of aircraft, then the utility of paying to develop a new plane becomes an important question. If DoD is unable to sever the link at least partially between improvement in performance and costs, prices would rise and procurement rates and total quantities would fall. Smaller fighter purchases would create shortages between inventories and requirements that, without force reductions, would require DoD to keep planes even longer than the venerable ages in current plans.

Chapter Four

The Joint Strike Fighter: Linchpin of the Administration's Aircraft Modernization Plans

The Joint Strike Fighter program will be the linchpin of the Department of Defense's modernization effort. It will account for about two-thirds of the fighter aircraft included in current DoD plans. What is open to dispute is whether a common aircraft design can answer the varied requirements of all three services—a multirole fighter for the Air Force, a long-range, ground-attack plane for the Navy, and a short takeoff vertical landing fighter for the Marine Corps. If DoD's modernization effort is to succeed, the Joint Strike Fighter program must be successful. It must meet three different sets of performance criteria and deliver the affordable aircraft that program officials promise. Because the Joint Strike Fighter is so central to DoD's plans, still early in its development, and taking a nontraditional approach, the program deserves close attention.

DoD's Plans for the Joint Strike Fighter Program

The Joint Strike Fighter program plans to design and develop several airframes or versions of airframes—possibly three—thereby mirroring the number of development programs it replaced (see Table 5 for a description of the services' requirements for the plane). A version that takes off and lands conventionally for the Air Force will be the lightest, least-complicated, and cheapest of the versions. A more rugged and possibly more complex version of the plane—strengthened to cope with the rigors of carrier operations and possibly modified to increase its stealth—characterize the Navy's version. The most radical differences are likely to appear in the Marine Corps/Royal Navy short takeoff vertical landing aircraft. The STOVL aircraft will require either an additional fan driven off a common engine or an increase in the engine's thrust to provide the short takeoff vertical landing ability that the Marines Corps seeks. (The option of adding an additional engine for STOVL planes was a part of a losing design proposal.) The specific design solution to the challenges will depend on which proposal is selected to enter the next phase of development.

Philosophy of the Joint Strike Fighter Program

Concerns about future prices underlie everything the Joint Strike Fighter program is trying to accomplish. The price of the aircraft receives more emphasis in the JSF's program plans than has been common in previous fighter development efforts. That emphasis is not surprising for a program that owes its existence to other programs canceled on the basis of their being unaffordable. Nor should it be surprising given the profound effects the program would have on future budgets and force structure if its ambitious cost goals are not met.

The push for keeping costs down has created two distinguishing features in the program: a high degree of jointness, and an attempt to incorporate commercial processes and existing technologies or developing technologies that will reduce costs. Jointness is not only evident in managing the program but also in the high degree of commonality that is expected from the three versions of the JSF. According to JSF program briefings, a joint fighter will cost about 18 percent to 25 percent less to develop, purchase, and operate than would three independently produced planes.

To achieve its ambitious cost goals, DoD expects to make the commonality of the systems those planes incorporate—airframe structure and systems, engines, and avionics—as great as possible. The JSF program also expects to save money during both its developmental stage and later when planes become operational.

The JSF program office has not yet released a detailed estimate for the development phase. But the Congressional Budget Office estimates that the JSF might cost $18.8 billion during the engineering and manufacturing development (EMD) stage, in addition to the $2.7 billion for developing the concept, bringing the total cost of development to $21.5 billion. That amount would be considerably less than earlier estimates of EMD funding for three separate designs.

Table 5.
Operational Characteristics for the Joint Strike Fighter

Characteristic	Service and Requirement		
	Air Force	Navy	Marine Corps
Sortie Generation Rate Significantly Greater Than Current Models of:	F-16	F/A-18	AV-8
Logistics Footprint Significantly Lower Than:	F-16	n.a.	AV-8
Payload (Internal) Plus Four External Stations	1,000 pound class Aim-120 and Gun	2,000 pound class Aim-120	1,000 pound class Aim-120
Survivability Enhancements[a]	Moderate	High	b
Radius (Nautical miles)	450 to 600	600 Minimum	450 to 550
Speed and Maneuverability	Capabilities Comparable to Current Multirole Fighters Such as F-16 and F/A-18		
Aircraft Carrier Suitability	No	Yes	STOVL
Basing Flexibility	No	No	Yes
Affordability (Unit flyaway costs in millions of 1994 dollars)	28	31 to 38	30 to 35

SOURCE: Congressional Budget Office based on Joint Initial Requirements Document (part of Department of Defense's Request for Concept Development).

NOTES: STOVL = short takeoff vertical landing; n.a. = not applicable.

a. Specific details of the services requirements for enhancement to survivability (largely through reductions to the planes' signatures) though unclassified, are not available to the public, according to DoD.

b. A plane that lands vertically may still have a large signature.

Funding for engineering and manufacturing development for the three planes JSF replaced might have totaled $29 billion to $36 billion. But spending the funds for JSF development would be considerably more than that spent to develop most earlier tactical fighters. (The Air Force's F-22 still holds the highest development price tag for a fighter.)

A new Department of Defense program to develop weapons usually heralds the improvements in capability that it will bring. Indeed, other design programs for fighters have promised upgrades in almost all areas of capability. The F-22 is expected to be stealthier and more maintainable than its predecessor—the F-15. It also is supposed to travel longer ranges at high speed and to possess avionics that will keep its pilots aware of their situation.

In contrast, a central theme of the JSF program is a willingness to trade off capabilities to meet cost goals. For example, the contractors have been instructed to estimate the sensitivity of the JSF's costs to desired capabilities so that the program and the services will be able to make trade-offs to lower the prices. Program office briefings forecast that emphasizing affordability in the design effort will yield additional savings of 15 percent to 30 percent over the life of the program.

The JSF program will also incorporate changes in acquisition procedures that a number of analyses of DoD's acquisition process recommended. Those reforms include "paperless" offices (increasing the use of networked computers in the contracting process) and use of "integrated product teams" (a management strategy from the business community that involves potential users in product design). The program also plans to make use of off-the-shelf commercial technology to produce savings.

Commonality: A Major Design Goal

In the Joint Strike Fighter program, commonality certainly receives more emphasis than in any fighter design since the Tactical Fighter Experimental (TFX or F-111) program of the 1960s. That program, like the JSF, was also intended to provide planes for a number of disparate missions: a medium-range nuclear-capable attack aircraft for the Air Force's former Strategic Air Command, a conventional strike aircraft for the Air Force's former Tactical Air Command, and a fighter interceptor for the Navy's carrier-based air wings. The Navy withdrew from the program, which ultimately produced planes that performed only the interdiction mission. As a result, DoD purchased the F-111 in relatively small quantities.

The JSF program's goals for commonality indicate that major portions of the fuselage, portions of the propulsion system, and most of the avionics would be common to all three versions. If the contractors find that level of commonality feasible, then the fuselages of all three versions of the Joint Strike Fighter would start out on a common production line as would the engine and, of course, the avionics.

Personnel in the Joint Strike Fighter program office have stated in briefings that about 80 percent of the value of planes' parts might be common, which is what the JSF program's cost goals assume.[1] According to the program office, that assumption would result in a reduction of up to 25 percent from the program's estimates of the life-cycle costs of three independent development efforts.[2]

Using Technology to Reduce Costs

The Joint Strike Fighter program also expects to develop technologies in ways that enhance affordability, while using existing technologies as much as possible. It plans to develop technologies that will reduce cost and weight and make planes easier and cheaper to maintain. In addition, it has directed contractors to choose technologies that entail lower risk, even if it means giving up some capability.

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1. One can measure commonality in several ways: by counts of parts, by weight, or by the cost of the parts. Designs can produce very different scores for commonality depending on which of those scoring methods is used.

2. The program office indicated that savings of 25 percent would be possible, but the program manager may be expecting even bigger savings from commonality. "[Program Manager Craig] Steidle told the *Armed Forces Journal International* that, as a result of commonality and new manufacturing techniques, the Joint Strike Fighter's unit flyaway cost could be reduced by as much as 30 percent." Glenn W. Goodman, Jr., "Joint Strike Fighter," *Armed Forces Journal International* (February 1996).

Consider one example of using existing technology —namely, using a derivative of the F119 engine, the engine in the F-22—instead of developing a totally new engine. Some of the program's goals for engine design might also be a good way to demonstrate technologies that will reduce cost. Perhaps by increasing reliability, the program plans to demonstrate an engine design that will cost less to operate than engines of the previous generation.

Another example of technologies that are aimed at reducing cost is the demonstration effort of Joint Advanced Strike Technology Integrated Subsystem Technology. In standard development efforts, many of the subsystems that make planes fly—such as the auxiliary power unit and the hydraulics—are developed as separate systems. That practice, however, leads to redundancy and excess weight. Proponents of integrated subsystems suggest that the reduced numbers of parts will lower the number of failures the system or systems suffer. The program will attempt to demonstrate a combined system that will perform the functions of a number of those subsystems.

The development effort for the Joint Strike Fighter will also try to lower technological risk by considering the capabilities of other aircraft with which the plane will operate. As a result, the services might discover that requirements for the JSF itself could be lowered. For example, the services might decide to accept JSF designs with less capable radars if the fighters could expect to receive targeting information from Joint Surveillance Target Attack Radar System aircraft (planes that survey the battlefield and can provide locations of ground targets to strike aircraft).

The services have agreed to preliminary requirements in JSF's Joint Initial Requirements Document. The purpose of that document is to provide guidance for contractors to use as they develop the concept rather than to specify the final capabilities for the various aircraft. For example, if the Navy later decides the estimates for ranges and payload specified in the statement of requirements are too short or too small, then it could drop out of the program in favor of initiating a new development effort. Conversely, the service could hold out for increases in capability that might raise the price of the program.

New Forms of Program Management

The JSF program was created at a time when budget pressures were strong and some revolutionary changes were occurring in the way DoD was managing acquisition programs. As a result, the program has a unique program management structure and approach, including freedom from traditional acquisition rules and oversight, its joint nature, and its emphasis on a number of reform initiatives in the acquisition process.

The Oversight of the JSF Program As Part of the New Philosophy. Management of research, development, and procurement of the Joint Strike Fighter reflects recent management initiatives by DoD to introduce greater flexibility into the acquisition process governing major weapon systems. The department traditionally required that all major weapon programs progress through a series of development and production phases separated by major decisions or milestones. All major weapon programs—those with an estimated total cost of more than $355 million for research and development or $2.1 billion for procurement (in 1996 constant dollars)—were required to pass each milestone successfully before proceeding to the next phase.

Old Policy. Under former policy, the department required approval of a statement outlining the need to perform a particular military mission before work on a major weapon system could begin. Before the Defense Acquisition Board—a high level DoD review committee—approved the need statement (Milestone 0) the military services developed a weapon system concept to meet the requirements of the approved military mission. The Defense Acquisition Board authorized the services at Milestone I to demonstrate and validate the weapon concepts they had selected.

The next milestone decision (Milestone II) authorized the services to begin engineering and manufacturing development to transform a weapon concept into operational subsystems and components. When the services demonstrated that engineering and manufacturing development efforts were sufficiently successful, the Defense Acquisition Board authorized the initial production of a weapon system in limited quantity to be used for operational testing before beginning production at a full rate (Milestone III).

New Rules. Since 1992, however, to avoid costs and delays from unnecessary reporting and review procedures, efforts to reform the acquisition process emphasized streamlining and management flexibility. The department also undertook a separate initiative to permit developing advanced technologies to demonstrate new military capabilities without committing the department to procuring a new weapon system. Such initiatives should allow the department to proceed with research and development of concepts and technologies for the JSF to an advanced stage of the acquisition process without being subject to the previous formal review processes.

DoD recently revised its management directives to ensure that essential requirements are met during the acquisition process. However, exceptions can be made when appropriate to permit a program to proceed without formal reviews and associated reporting requirements. A March 1996 directive states that a management review of each weapon program should ensure that major acquisition requirements are met but may be tailored to reflect a program's particular characteristics.[3] According to the new directive, "Certain core issues must be addressed at the appropriate milestone for every acquisition program." However, "tailoring may be applied to various aspects of the acquisition process, including program documentation, acquisition phases, the timing and scope of decision reviews, and decision levels."[4] The new rules permit a program to enter the acquisition process at any stage of development or production that the Defense Acquisition Board deems appropriate. In some cases, if DoD management concurs with recommendations from a program office, a major weapon program may proceed to more advanced stages of the acquisition process without undergoing formal milestone reviews.

Through bypassing a traditional program initiation and Milestone I review, the JSF program reflects DoD's new, more flexible approach to acquisition management (see Table 6 for schedule). The Defense Resources Board—an oversight body that the Deputy Secretary of Defense chairs—did not formally approve a mission need statement for the JSF as has been required in the past. But the Joint Requirements Oversight Council—made up of members of the Joint Staff and chaired by the Vice Chairman of the Joint Chiefs of Staff—reviewed a Joint Initial Requirements Document that the services submitted in August 1995 that initiated the program. Moreover, although the Defense Acquisition Board held no formal Milestone I review, it did hold a special review late in the summer of 1995 to examine the Concept Demonstration Phase—the initial phase of the acquisition process—and subsequently reviewed the package asking contractors for proposals to develop concepts. As part of that review, the Defense Acquisition Board also reviewed the cost estimates for program development.

Although those steps toward greater flexibility may streamline and accelerate the acquisition process for the Joint Strike Fighter, they could also introduce a risk that DoD leadership could overlook important elements of program planning, developing, testing, and reviewing. However, if the Defense Acquisition Board holds a regular Milestone II review before the program enters engineering and manufacturing development, the risk that such oversights could occur might be reduced.

Other Reforms. The JSF program management structure incorporates a number of acquisition reforms. The program has arranged for the early and intensive involvement of a number of personnel who will be affected by decisions about the design (according to a program briefing that approach will involve industry and "war fighter"—a potential user of the system—earlier in the process). To ensure that involvement, the JSF program is making heavy use of Integrated Product Teams that provide broader involvement earlier.

The program is also following other suggestions for reforming acquisition in attempting to simplify and streamline the contracting process. For example, the government's requests for proposals for early phases of the program and the contractors' bids were prepared and submitted using networked databases, which the program office argues greatly simplify solicitation and source selection.

The program also has an unusual joint service management structure. The people who devised the program attempted to ensure that the services would be equal partners in the design phase. For example, the Navy and Air Force are expected to alternate in supplying program managers, and the program office is to

3. Department of Defense Directive, *Executive Summary*, DoDD 5000.1 and DoD 5000.2R (March 15, 1996).

4. DoDD 5000.1 and DoD 5000.2R, p. 8.

Table 6.
Program Schedule for the Joint Strike Fighter as It Moves Through the Acquisition Management Process

Milestone 0: Approval to Explore Concept	Milestone I: Approval to Begin a New Acquisition Program	Milestone II: Approval to Enter Engineering and Manufacturing Development	Milestone III: Approval to Enter Production, Fielding/Deployment, and Operation Support Phase
Department of Defense Milestones and Requirements			
Reviewed by DAB and JROC	Program provides and DAB reviews: CAIV APB Exit criteria	DAB approves: acquisition strategy CAIV APB Exit criteria	DAB approves: acquisition strategy CAIV Phase III exit criteria Full-rate production
Joint Strike Fighter Phases and Status			
Phase 0: Concept Development	Phase I: Program Definition and Risk Reduction	Phase II: Engineering and Manufacturing Development	Phase III: Production, Fielding, Deployment and Operating Support
Joint Strike Fighter Concept Studies, 1994	Joint Strike Fighter selects two teams of contractors for concept development, 1996	Milestone II: Joint Strike Fighter in 2001	2009 (formal milestone review)
The then-Joint Advanced Strike Technology program was a technology exploration program, not an acquisition program at this point	Joint Strike Fighter becomes major defense acquisition program in May 1996.	First formal review for Joint Strike Fighter.	2009 (formal milestone review) Joint Strike Fighter first operational around 2010

SOURCE: Congressional Budget Office based on information from the Department of Defense.

NOTES: DAB = Defense Acquisition Board; CAIV = Cost as an Independent Variable; JROC = Joint Requirements Oversight Council; APB = Acquisition Program Baseline.

alternate reporting to Navy and Air Force secretariats. In the past, even in programs in which DoD expected joint purchases, program oversight usually has been the responsibility of a single service.

Manufacturers Compete for Joint Strike Fighter Development Contracts

In response to its request, the Joint Strike Fighter program received three proposals from aerospace contractors to develop conceptual designs for the plane. Two companies—the Boeing Company and the Lockheed Martin Corporation—submitted proposals individually. The third proposal was submitted by a team composed of McDonnell Douglas Aerospace, Northrop Grumman Corporation, and British Aerospace Defence Ltd. The program office announced on November 16, 1996, that the Boeing and Lockheed proposals had been selected.

The winning teams will build and fly three versions of two demonstrators—the X-32A, B, and C and the X-35A, B, and C ("A," "B," and "C" designate, respectively, Navy, Air Force, and Marine Corps versions). Those planes will demonstrate STOVL capability and low-speed handling—an important design feature for planes that take off from and land on aircraft carriers.

The next major decision that affects which companies participate in the program is Milestone II, currently scheduled to occur in 2001, the beginning of the engineering and manufacturing development stage. At that point, according to current plans, DoD will select a single proposal for developing and producing the three versions of the Joint Strike Fighter.

Concerns About the Joint Strike Fighter Program

Personnel in the Congress and the Executive Branch have expressed a number of concerns about the Joint Strike Fighter program, especially whether the program will fall victim to historical trends or be able to avoid them as it promises. Those potential problems could dim the chances for the hoped-for reductions in costs.

Concerns about Commonality

To cut costs, the Joint Strike Fighter program emphasizes commonality more than probably any other military aircraft design effort. But skeptics are already pointing to several problems related to commonality.

Warnings From the Past. The Department of Defense's past experience with joint programs does not engender optimism about the prospects for attaining high levels of commonality. Many defense programs begin with the expectation of joint purchases by the services, but those expectations are seldom met. In the mid-1980s, for example, the Navy and the Air Force planned to buy each other's planes. The Navy agreed to buy a version of the Air Force's F-22 (then called the Advanced Tactical Fighter) to replace its F-14 fighter aircraft, and the Air Force agreed to purchase the Navy's Advanced Tactical Aircraft, which was eventually designated the A-12, for its strike mission. Subsequent events—including substantial reductions in the perceived threat and the cancellation of the A-12—disrupted those plans. The Navy now has no plans to purchase a version of the F-22.

The Marine Corps' V-22 is another example of high hopes for jointness being dashed during development. DoD originally planned to purchase about 1,200 V-22s, including about 600 for the Marine Corps, 230 for the Army, about 300 for the Navy, and about 80 for the Air Force. After several years of development, the Army dropped out. The Navy cut its planned purchases from 300 planes to about 50 planes, which are still in DoD plans. The Marine Corps also cut planned buys to 425 aircraft, and the Air Force may still buy 50 planes for special operations.

Other examples of decreasing commonality between early concepts and production include the AV-8B Harrier and the F/A-18E/F programs (see Table 7). Those planes were supposed to have 50 percent and up to 70 percent, respectively, in common with earlier versions. According to some estimates, their airframes ended up with very little or no commonality.

The Navy's T-45A Goshawk, a trainer that operates on a carrier deck, was expected to have a high degree of commonality with the United Kingdom's Hawk, a land-

based trainer. It, too, ended up with little commonality with the earlier version. The JSF program office argues, however, that the early involvement of the three services in the design process will improve the chance that the program will succeed in producing planes for all three services.

Commonality Requires Compromise. Common sense suggests that a joint program design is likely to be a compromise. On the one hand, such a compromise could mean that the service with the most modest requirements in terms of capability (the Air Force) would have to accept a higher price and capability than it needs so that the needs of the services with the greater capability requirements (the Navy and Marine Corps) could be met.

On the other hand, the Navy might have to give up on some of its technical desires to avoid pricing the Air Force and the Marine Corps out of the market. If history is a guide, both outcomes are likely—the planes are apt to be more costly than Air Force requirements might dictate, but provide less capability than the Navy might desire. (Also note that price increases and decreases in capability are consistent with the history of many single-service programs as well. DoD's development programs usually provide less capability at higher prices than early optimistic estimates suggest.) The program's success will depend on persuading the services to lower their expectations from the stand-alone programs they might have without the Joint Strike Fighter.

Navy Concessions

According to briefings the Congressional Budget Office has received from the Joint Strike Fighter program office, the Navy has already made several concessions in its requirements. The Navy has argued that the planes in its fleet need two pilots and two engines for a number of years. The service has indicated a willingness to accept a single engine and a single pilot. Both of those concessions could keep the price of the Navy's JSF version down. Always present is the concern that the Navy might attempt to withdraw from the program when the JSF reaches engineering and manufacturing development, when the service must find larger yearly sums to pay its share of the fighter's development costs.

To keep prices down, the Navy might also need to accept lower levels of stealth and shorter ranges than it had originally expected from a strike fighter. But significant concessions on those requirements might also

Table 7.
Trends in Commonality During Selected Development Programs

Aircraft[a]	Early Estimate	Midterm Estimate	Most Recent Estimate
F/A-18E/F	60 to 70 (1988)	25 (1991)	0 (1995)
AV-8B	50 (1978)	5 to 10 (1980)	0 to 5 (1981)
T-45A	64 (1992)	10 to 12 (1988)	8 to 10 (1990)
P-7[b]	59 (1988)	0 to 5 (1989)	Terminated

SOURCE: Congressional Budget Office based on Department of Defense data.

NOTE: Table uses examples of recent development programs. Weight of common parts are expressed as a percentage of total airframe weight.

a. Reflects common features of the airframes with earlier models. Commonality in subcomponents may be higher. For example, the Navy argues that 90 percent of the F/A-18E/F avionics subcomponents are the same as those in the F/A-18C/D.

b. Reflect commonality with the P-3 aircraft. The P-7 design was originally expected to be a modified P-3.

endanger the Navy's support for the program. A naval Joint Strike Fighter will need to offer substantial improvements in those areas above the capability of the F/A-18E/F Hornet that the Navy is purchasing to become its fleet workhorse for the first decade of the 21st century.[5]

The Air Force's Concerns

Air Force decisionmakers have indicated that they will drop out of the program if the price increases substantially. Specifically, the service is worried that it will be forced to pay extra to buy a plane that has more capability than it needs. General Joseph Ralston stated that the Air Force would not be able to afford JSF aircraft that are sized to meet Navy requirements.[6]

Air Force sensibilities about these issues are likely to be highly important to JSF personnel, since the Air Force is slated to purchase two-thirds of the planes. Nonetheless, DoD's track record would lead one to expect significant growth in most planes' procurement prices during the development phase—growth that could easily drive the price well above the $28 million price goal (in 1994 dollars).

The Marine Corps' Concerns

The Marine Corps also raised concerns about whether the Navy's desire to carry 2,000 pound bombs (rather than the 1,000 pound bombs called for under Air Force and Marine Corps requirements) would drive up the price of the Joint Strike Fighter. Lieutenant General Harold Blot, when he was the Marine Corps' Deputy Chief of Staff for Aviation, was quoted as saying that, "the last thing we want to happen is to have 300 airplanes drive [the design of] 2,500 airplanes."[7] Informal sources suggest that the Air Force might be reconsidering the desirability of carrying larger weapons.

Concerns About Technology

As with commonality, concerns could be raised about the ability of the JSF program to wring savings from development by using existing (or mature) technologies to the greatest extent possible. As an example, designs for the Joint Strike Fighter may need an engine with more thrust than that of the F119, largely for the Marine Corps versions. Making such sizable increases in thrust while maintaining reliability might be difficult to attain from an engine originally designed for the F-22. Moreover, it will doubtless require jumping some technological hurdles, such as enhanced cooling, which might be challenging.[8]

According to some critics, DoD has found it difficult to make substantial increases in the performance of existing engines. The General Accounting Office, for example, argues that the Navy has not been able to get the roughly 38 percent increase in thrust it desired from its F404 engine to make it the F/A-18E/F's F414.[9] If GAO is right, and if increases in thrust expected from the F119 exceed 20 percent in the eventual development plan, they would exceed the increase that the Navy may be able to get out of the upgrade from F404 to F414. Proponents of the JSF maintain that thrust has increased by similar percentages when commercial engines have been modified.

Some analysts are also skeptical about the promises of cost savings from integrating systems, such as what the Joint Advanced Strike Technology Integrated Subsystem Technology program proposes. Even if goals are met and the program develops a way to combine a number of systems into one, concerns could be raised about the increased maintenance costs of the single system. Although an integrated system may reduce weight, and thus cost less to purchase, it may be subject to the problem that a failure anywhere in the system may require maintenance to the entire system. Designers can attempt to deal with this problem, perhaps by designing modular systems, but trade-offs may be inevitable between integration and reducing the cost of re-

5. For a discussion of concerns about the F/A-18E/F program, see General Accounting Office, *F/A-18E/F Will Provide Marginal Operational Improvement at High Cost*, NSIAD 96-98 (June 1996).

6. Tanya Bielski, "Navy's JAST Requirements Make Program Too Expensive--Ralston," *Defense Daily*, November 1, 1995, p. 141.

7. "Marines to Scrutinize JSF [Joint Strike Fighter] Internal Carriage," *Aerospace Daily*, March 1, 1996, p. 322.

8. Office of the Under Secretary of Defense for Acquisition and Technology, *Report of the Defense Science Board Task Force on Concurrency and Risk of the F-22 Program* (April 1995).

9. General Accounting Office, *F/A-18E/F Will Provide Marginal Operational Improvement* (June 1996), p. 29.

pairs. Also, decreasing redundancy in flight controls could make planes more vulnerable if they are hit.

A major theme of the effort to use significant amounts of existing technology is that the services will have to reduce the emphasis on state-of-the-art technology. Choosing technologies that are already clearly understood should cut costs, but the service participants in the Joint Strike Fighter program may find it difficult to forgo technologies that promise substantial improvements in capability.

The Joint Strike Fighter has no formal requirements for capability, since it has only recently become a proper acquisition program rather than an exploration program. But the concerns the services have about trade-offs involved in achieving commonality may find their match in the concerns the services have about capabilities lost to cut design and production costs. For example, the services' stealth requirements may be of high enough priority to force the program to incorporate advanced technologies that could drive up costs.

Concerns About Capability Trade-Offs

Because of the program's emphasis on affordability, JSF's success will hinge on constraining costs. Yet the price of fighters has always grown from one generation to the next. Since the United States expects significant improvements in capability from each new generation of weapons and pays for what it gets, some growth in prices is inevitable. If that improvement is the underlying cause of such growth, DoD's plans to deemphasize capability might hold prices down. But some of the goals for the JSF's technical performance create potential for significant cost growth.

The Joint Strike Fighter program intends to keep costs low by trading off capabilities. The catch is that only a limited range of trade-offs may be acceptable. Indeed, the JSF program office has compiled an impressive list of desired capabilities. Even if those desired capabilities are only goals, contractors appear to be attempting to meet them (and, they argue, succeeding) in their proposals for developing a concept. The list also indicates the high priority that the JSF program office is placing on cost. It is unusual for a program to include cost among its design goals.

The Congressional Budget Office asked all of the contractors who submitted proposals to develop the concept for the Joint Strike Fighter to give examples of desired capabilities they traded off to meet cost goals. No contractor provided an example of such a trade-off, though trade-offs were apparently made when the operational requirements were determined. New development efforts are typically justified on the basis of the improvements they offer over the current generation's weapons. The eventual designs for the Joint Strike Fighter will need to provide capabilities that exceed those of the current fleet in several areas, particularly in reduced observability. Otherwise, DoD may find it difficult to justify the program.

Concerns About Acquisition Reform

Some defense analysts raise another concern about the current Administration's promises to cut costs. They argue that they have heard similar promises from previous administrations that were not realized. A good example is a concept developed in the 1970s under then Deputy Secretary of Defense David Packard. Mr. Packard's concept, called "design to cost," bears an uneasy resemblance to the current administration's plan to treat "cost as an independent variable"—that is, to provide designers with insights about how requirements for increases in capability will affect costs.

A recent article in the Defense Systems Management College's publication, *Program Manager*, also raises some warnings. It suggests that cost increases were generally higher in programs that used the design-to-cost philosophy than in those that did not.[10] But the article goes on to argue that today's cost as an independent variable design philosophy may be more successful since it is a more sophisticated approach to improving costs. The article points to the Joint Direct Attack Munitions (JDAM) program that is entering production as proof that the newer approach is successful. According to the article, as a result of using that philosophy in munitions design, JDAMs will cost less than estimated rather than more.

Nonetheless, some defense analysts still raise a skeptical eyebrow at claims for the new philosophy,

10. B.A. "Tony" Kausal IV, "Controlling Costs—A Historical Perspective," *Program Manager*, November-December 1996, pp. 22-28.

despite the Joint Direct Attack Munition program's promise of success. They point out that the JDAM program will produce a munition rather than a plane. For that reason, it is significantly less complex than the JSF program. Greater complexity could increase the chance for cost hikes.

Concerns About the JSF Schedule and the Potential for Concurrency

Myriad factors could cause the schedule for the Joint Strike Fighter to slip, including technical problems and insufficient future funding. Such changes could increase the costs of the program or the risk of concurrency—or even result in shortages in the services' inventories of combat aircraft.

Schedule Slips Caused by Testing Delays. Considerable debate exists within the Department of Defense about the desirable degree of overlap between development and production (known within the trade as concurrency). On the one hand, it is important to complete sufficient testing before configuring factories for full production and purchasing significant numbers of weapons. On the other hand, DoD wishes to test weapons that come off the production line and to avoid small production quantities or gaps in production once it has begun. If design flaws are discovered in testing once production has begun, they can result in costly modifications, in a lack of commonality between weapons produced before and after the flaws were uncovered, and, in the worst case, weapons that cannot perform their missions adequately.

By one hallmark of concurrency—purchasing more than 10 percent of the total procurement quantity before testing is complete—the Joint Strike Fighter is unlikely to be concurrent, if total quantities remain high. To be defined as concurrent by that definition, 300 Joint Strike Fighters would need to be bought before testing is complete. Based on the current test schedule, the program would have only bought or paid long-lead funding for about 230 planes before operational testing is completed. Although producing 8 percent of a program's production quantities does not meet the DoD definition of concurrency, the planes could still cost $12 billion of today's dollars.

In all likelihood, the JSF's schedule will slip, either for technical reasons or because the services find they cannot afford to pay for the annual quantities in today's plan. The F-22 is the most recent fighter development program and as such may provide lessons about the Joint Strike Fighter. A glance at that plane's program schedule might sober expectations of beginning JSF procurement in 2005—about nine years from now.

The F-22 was originally scheduled to enter the demonstration and validation phase of its development (Milestone I) in 1984, perhaps a similar development stage to the JSF's today. In 1985, F-22 designers anticipated that the plane would enter production in 1992, eight years later. Since those early program days, the F-22 has experienced slips for a number of reasons, even though for many years it has been placed high on Air Force priority lists—sometimes at the very top. Given the unusual nature of the JSF program's development, pinning down exactly where the JSF is in the development cycle is no easy matter. But it went through a high-level review—perhaps the equivalent of a Milestone I—in the spring of 1996.

If the F-22 program was to experience no further delays, initial production of F-22s at a low rate would begin in 1999—13 years after Milestone I and seven years after the production starting date projected at Milestone I. If the Joint Strike Fighter program was to experience similar delays in development but needed to keep close to the original production schedule to avoid force cuts, concurrency could result under the 10 percent rule.

JSF watchers may wish to check on several factors to evaluate the realism of the JSF program's plans for its development schedule. Those factors include the development time planned between engineering and the contract award for the engineering and manufacturing development phase, the first flight, the number of test articles, and flight test hours. The first flight is scheduled for 42 months after the contract is awarded. That estimate is based on experience with the development of four fighters (F-14A, F-15A, F-16A and F/A-18 A/B), plans for the technology maturation program, and the development of the JSF concept program that includes flying demonstrators.

However, those four aircraft may not be the best cases on which to plan the JSF schedule. In fact, the

F-22 might be a better one if program scope and complexity are considered. The F-22, which had a similar demonstration program before the engineering and manufacturing development stage, was scheduled at Milestone II to take 50 months to first flight (eight months longer than the time span planned for the JSF). Since then, the time to the F-22's first flight has increased to 70 months, and indications of further delays are apparent. Although the Air Force attributes much of this slip to reductions in funding by the Congress and the Office of the Secretary of Defense, some portion is likely to be the result of the complexity of the program's technical scope. No evidence indicates that the JSF, charged with developing a family of three aircraft, will face fewer challenges than the F-22.

As of November 1994, the F-22 program included a total of about 5,200 flight test hours and planned on flying them using nine test aircraft. The average number of flight hours—23.3 per plane per month—exceeds historical experience. Other fighter development programs that have successfully completed development have flown averages of about 11 hours (F-15) to about 16.5 hours (F-16) per plane per month. Those comparisons suggest that the already concurrent F-22 program may be in line for further slips—a suggestion that is supported by reports that the fiscal year 1998 budget submission will propose a program delay.

Unfortunately, most of the information that would permit the Congressional Budget Office to evaluate the concurrency in the JSF program in more detail is proprietary or nonexistent. As part of their proposals, contractors are expected to identify the development time needed before first flight, how many test vehicles they will build, and how many hours they expect to fly. If development funds for a program pay for too few test vehicles or too few hours, then both funding and scheduling can be optimistic.

Scheduling Slips Caused by Funding Shortages. The schedule for the Joint Strike Fighter could slip if requirements for development funding increase. The then-JAST program already went through a program delay in 1996, when the first estimates of funding for developing a concept appeared in the budget. According to reports from the program office, an early review of the scheduled program in 1996 resulted in a slip of six months in the start of engineering and manufacturing development, though the JSF program apparently did not delay planned procurement. The administration also added money to its estimates of program funding. Even so, the program's development costs could climb. Recent efforts to develop aircraft have experienced cost hikes that average about 21 percent above the original estimates for engineering and manufacturing development. If funding to develop the Joint Strike Fighter was to rise by that average, development costs for the program would total $26 billion—about 15 percent more than the cost to develop the F-22.

DoD insiders claim that the program will be fully funded in the new Future Years Defense Program. Moreover, the JSF program probably has sufficiently high priority in DoD to compete successfully for funds. But the JSF has a number of competitors for funding over the six-year period that makes up the FYDP, and many analysts believe that DoD will need additional funding or will need to make further program cuts to make ends meet during this period. As a result, adding funds for development if requirements increase during this period could be difficult.

Funding shortfalls in the period beyond the Future Years Defense Program years could easily lead to slips in the schedule for the JSF program. That possibility applies even if the program itself does not experience increases in development and procurement costs for technical reasons. Since such slips can lead to less efficient production or production delays, they can also cause prices to rise.

Concerns About the JSF's Impact on the Industrial Base

The aerospace industry has undergone a number of notable mergers over the last few years with Lockheed's acquisition of General Dynamics' Fort Worth Aircraft Division, the merger of Grumman Aircraft Corporation with Northrop Corporation, and the planned merger of McDonnell Douglas Aerospace and the Boeing Company. Some analysts have expressed concerns that the Joint Strike Fighter program—by comprising such a large share of DoD's future fighter purchases—might spawn further consolidation in the industry or force contractors not involved in its production out of the

fighter aircraft business.[11] As the argument goes, such a single manufacturer or manufacturing team would be able to reap monopoly profits and push up the cost of the plane.

Furthermore, if the Joint Strike Fighter was to drive the F/A-18E/F out of production, the winning contractor or team could easily become the sole producer with the experience to develop and build any fighter aircraft thereafter. One way to prevent that problem might be to bring on a second source and create two JSF production lines. That approach would ensure that more than one manufacturer retains the skills to develop and build fighter and attack aircraft. But even if other manufacturers retain those skills, the U.S. government could face significant expenses if it had to qualify a second producer.

Concerns about limiting competition have also been expressed about the engine for the Joint Strike Fighter. Both of the contractors involved in the JSF competition are using variations of Pratt and Whitney's F119 engine (that powers the F-22). The JSF program has received Congressional direction to keep the engine design competitive by also qualifying General Electric's F120 engine (a design that lost to the F119 in the F-22 design) for the JSF program.

However, despite the program's apparent agreement to that direction, proponents of an engine competition argue that funding for the second engine is too low to make it an effective alternative. The F120 engine is scheduled to receive about one-tenth of the funding slated for the other engine ($90 million versus $900 million) during the concept development phase of the JSF program. Moreover, at least based on last year's plans, no funds will be slated for the F120 design during JSF's next development phase—engineering and manufacturing development. (The JSF program indicates that the newest program plans do include funds for F120 development during the latter stage.) The program argues that significantly greater spending on the second engine is not needed since plenty of time will be available for developing the second engine once the developer for the airframe is selected.

The lack of competition in purchases of military aircraft may pose less reason for worry than it would in the private sector. As a single buyer, the government brings enormous leverage to the bargaining table. Moreover, DoD pays substantial penalties for keeping excess design and production capacities. Such penalties may outweigh the benefits of competition. Cold War concerns about the need for production surges or for the technological advances that might arise from companies keeping a competitive edge are less compelling today. Further, making the most efficient use of DoD's dollars may be more persuasive in an era of tight budgets.

Potential Problems with the Structure of Program Management

The Joint Strike Fighter program is relying on its unique program structure and freedom from old acquisition rules to achieve jointness, commonality, and lower prices. However, those methods are an unproven mix in a program as complex as developing a tactical fighter. Sharing management responsibilities—and trading them off every few years—probably increases both the services' commitment to the program and the likelihood that management will be sensitive to the concerns of both services. But that arrangement also leads to frequent changes in program managers. Shortening the program manager's tenure is at odds with recommendations made in some studies of problems with the defense acquisition process. Past reformers of the acquisition process have recommended that acquisition executives remain in place for long periods to improve continuity and thus increase expertise and enhance accountability.

Program officials often cite the JSF program's freedom from formal acquisition rules and oversight as automatically lowering costs. But that freedom may come at a price. DoD's formal acquisition process represents an attempt to reduce government risk, to avoid proceeding too far into a program—and spending too much money—without ensuring that programs will produce needed, usable products.[12] The process also strives to

11. See, for example, Richard Aboulafia, "From JAST to JSF," *Military Technology*, Bonn, Germany: Wehr und Wissen, May 19, 1996.

12. See, for example, General Accounting Office, *Combat Air Power: Joint Mission Assessments Needed Before Making Program and Budget Decisions*, NSIAD-96-177 (September 1996) for a discussion of some of the limitations of DoD oversight of tactical aviation programs.

ensure that the cost estimates are reasonable, that the program is justified by the threat and is the best choice among available alternatives, and that program management has outlined a reasonable acquisition strategy. Some decisionmakers might argue that the Joint Strike Fighter program is both too costly and too important to the future of tactical aviation to forgo even early formal reviews.

Indeed, recent Congressional reports have suggested that DoD should engage in a more rigorous review of the JSF requirements before proceeding too much further with the development program.[13] Also, the decision by Dr. Paul Kaminski, the Under Secretary of Defense for Acquisition and Technology, to change the status of the JSF program may signal that the Administration has rethought its earlier decision to skip a number of reviews, even if the change in status came about as the result of Congressional pressure. The House National Security Committee—joined by the Senate in Conference—directed the Institute for Defense Analyses to perform an independent analysis of alternatives to the JSF by spring 1997, an analysis similar to what DoD refers to as an Analysis of Alternatives. It also directed the Cost Analysis Improvement Group, part of the Office of the Secretary of Defense, to evaluate the Institute's estimates of development and production costs for the Joint Strike Fighter and for alternatives to the program.

All in all, then, it would appear that the JSF program is headed for greater scrutiny right now. Where that will lead is for the moment hard to predict.

13. U.S. House of Representatives, *National Defense Authorization Act for Fiscal Year 1997*, conference report to accompany H.R. 3230 (July 30, 1996), pp. 36-37.

Chapter Five

Options for Tactical Aircraft Modernization

When confronted with funding problems, the services often reduce force structure. Since the late 1980s, the Air Force has cut its "wing equivalents" of tactical fighters by almost 50 percent. The Navy, which does not use wing equivalents to describe its fighter forces, has ostensibly made more modest reductions in its forces. Carrier-based air wings—the Navy's measure of tactical air forces—have only been decreased by about a quarter. But the Navy has cut the number of planes per wing over the years. It plans to use aircraft in some Marine Corps squadrons to meet mission requirements both in its wings and in Marine air wings. Future funding problems could well lead to even sharper reductions in force.

The following alternatives illustrate varying approaches to dealing with long-term funding problems. Each option produces savings, though only the last alternative discussed would reduce future funding to the amount associated with shares for tactical aircraft during the 1974 to 1997 period.

The first option assumes that future leaders eliminate the joint focus of the efforts to develop the Joint Strike Fighter and instead concentrate on developing a plane for only one or two services. One version of that option—IA—would make purchases for the Air Force, since that service needs the largest number of planes. It assumes that Marine Corps forces dedicated to the close-air-support mission would be eliminated, thus lowering requirements and the need to purchase planes. In a variation on that theme, Option IB would develop planes for Navy and Marine Corps forces, and would eliminate developing new aircraft for the Air Force.

The second option would capitalize on already existing aircraft or efforts to develop aircraft by purchasing for one service the planes currently designed for another. That option would cost less than the Administration's plan or the first version of Option I but more than that of past funding shares. Option III would purchase today's less expensive aircraft and develop fewer more costly new ones. Both Options II and III would seek to purchase enough planes to meet current force levels, whereas Option IV would make proportional cuts in all programs, to get roughly to previous shares of funding, and would accept the lowered force levels that result.

Option IA: Set Priorities for Tactical Aircraft Requirements—Emphasize Air Force

Option IA would restructure the Joint Strike Fighter program to emphasize one of its three roles—namely, replacing the F-16 in the Air Force. The option would also purchase the F-22 for the Air Force fighter mission in the quantities that the service is currently planning (see Tables 8 and 9 for types and quantities of planes purchased under alternatives).

Table 8.
Types and Quantities of Aircraft Purchased for the 1997-2001 Period Under the Administration's Plan and Four Options

Aircraft	Administration's Plan	Options						
		IA	IB	IIA	IIB	IIIA	IIIB	IV
				Air Force				
F-16	6	6	222	6	6	228	150	6
F-15E	6	6	92	6	6	52	52	6
F-22	40	40	0	40	40	20	20	40
F/A-18E/F	0	0	0	0	0	0	0	0
JSF(AF)	0	0	0	0	0	0	0	0
Subtotal	52	52	314	52	52	300	222	52
				Navy				
F/A-18C/D	6	6	6	6	6	280	280	6
F/A-18E/F	162	162	162	162	162	0	0	162
A/F-117X	0	0	0	0	0	0	0	0
F-22N	0	0	0	0	0	0	0	0
JSF(N)	0	0	0	0	0	0	0	0
Subtotal	168	168	168	168	168	280	280	168
				Marine Corps				
New AV-8B	0	0	0	0	0	12	12	0
Comanche	0	0	0	0	0	0	0	0
JSF (ASTOVL)	0	0	0	0	0	0	0	0
Subtotal	0	0	0	0	0	12	12	0
Total	220	220	482	220	220	592	514	220

SOURCE: Congressional Budget Office.

NOTE: JSF = Joint Strike Fighter; ASTOVL = advanced short takeoff vertical landing.

a. All F-16s purchased are C models for all options except Option IIIB. Option IIIB purchases are improved F-16s called the F-16 Multistaged Improvement Program (MSIP), except for the first six, which are F-16 "C" models.

However, it would limit efforts to modernize carrier-based naval wings to only the currently planned purchases of the F/A-18E/F. It would also not purchase any planes to replace the Marine Corps' AV-8B aircraft. Since AV-8B aircraft are dedicated to the close air-support mission, the option assumes that only Marine Corps F/A-18 aircraft, along with Air Force and Navy planes, would provide such support to the Marine Corps ground forces.

A number of defense experts have recommended consolidating missions in the tactical aircraft arena—that is, abandoning certain tactical aviation missions in one service and having that service rely on the other services for its air support. The choice illustrated by this option of having the Marine Corps forgo its close air-support mission reflects a proposal that appeared in a House National Security Committee report. The committee's report on the fiscal year 1997 authorization request directed that no more money be spent on designing an advanced short takeoff vertical landing aircraft for the Marine Corps—though the suggestion did not appear in final bill language.[1] Designing planes to

1. House Committee on National Security, *Report on National Defense Authorization Act for Fiscal Year 1997*, to accompany H.R. 3230 Report 104-563 (1996), p. 131.

perform that function may be the most challenging task for the JSF program.

Abandoning a development effort to add a new stealthy plane to the Navy's carrier decks reflects the possibility that the Navy might withdraw from the Joint Strike Fighter program of its own accord if the Department of Defense's goals for the plane's funding and performance prove optimistic. Furthermore, the Navy might find that the F/A-18E/F provides sufficient range and stealth to do without the Joint Strike Fighter.

Risk and Balance

Option IA proposes developing a much less complex Joint Strike Fighter and would design a plane only for the Air Force mission. Therefore, the option's development risk would be lower than that of the Administration's plan (see Table 10). The Congressional Budget Office chose to modernize Air Force fighter forces in this option because, under the Department of Defense's plan, the Air Force would be purchasing JSFs in the greatest numbers.

Table 9.
Types and Quantities of Aircraft Purchased for the 2002-2020 Period Under the Administration's Plan and Four Options

Aircraft	Administration's Plan	Options						
		IA	IB	IIA	IIB	IIIA	IIIB	IV
Air Force								
F-16	0	0	672	0	0	540	618	0
F-15E	0	0	400	0	0	162	162	0
F-22	398	398	0	398	398	220	220	200
F/A-18E/F	0	0	0	1,202	1,202	0	0	0
JSF(AF)	1,320	1,320	0	0	0	550	550	556
Subtotal	1,718	1,718	1,072	1,600	1,600	1,472	1,550	756
Navy								
F/A-18C/D	0	0	0	0	0	786	786	0
F/A-18E/F	838	838	838	1,138[a]	1,138[a]	0	0	488
A/F-117X	0	0	0	0	204	0	0	0
F-22N	0	0	0	180	0	0	0	0
JSF(N)	180	0	b	0	0	96	96	92
Subtotal	1,018	838	838	1,318	1,342	882	882	580
Marine Corps								
New AV-8B	0	0	0	0	0	48	48	0
Comanche	0	0	0	258	258	0	0	0
JSF (ASTOVL)	480	0	660	0	0	228	228	146
Subtotal	480	0	660	258	258	276	276	146
Total	3,216	2,556	2,570	3,176	3,200	2,630	2,708	1,482

SOURCE: Congressional Budget Office.

NOTE: JSF = Joint Strike Fighter; ASTOVL = advanced short takeoff vertical landing.

a. Includes purchases for Marine Corps squadrons.

b. CBO assumed advanced short takeoff vertical landing versions of the Joint Strike Fighter are purchased for the Navy's carrier air wings. Those planes are included in Marine Corps purchases.

Table 10.
How the Options Affect Risk In the Development Phase and Level of Sophistication of Fleet

Alternative	Development Risk		Advanced Fighters' Share of Fleets in 2020 (Percent)[a]	
	Air Force	Department of the Navy	Air Force	Department of the Navy
Administration's Plan	High	High	81	93
Option IA: Set Priorities for Development (Emphasize Air Force Missions)	High	Medium	81	91
Option IB: Set Priorities for Development (Emphasize Naval Missions)	Low	High	0	93
Options IIA and IIB: Build on Existing Development Efforts	Medium	Medium	75	100[b]
Options IIIA and IIIB: Emphasize Current Generation Aircraft	Medium	Medium	30	17
Option IV: Make Proportional Cuts	High	High	57	79

SOURCE: Congressional Budget Office.

a. Advanced fighters are assumed to be the F-117, F-22, F/A-18E/F, and the Joint Strike Fighter.

b. Rounds to 100 percent.

The option would represent a return to the Bush Administration's plan to develop a multirole fighter. But since the option would require the Air Force to shoulder a larger responsibility for air support of ground operations, designers would need to focus their attention on the close air support and battlefield air interdiction missions—more than they might have in the design for the Multirole Fighter. Reducing the emphasis on air-to-air missions for the JSF might be acceptable if DoD goes forward with its plan to purchase large numbers of F-22s.

One of the alternatives that DoD evaluated in a roles and missions study in 1993 was to eliminate Marine Corps squadrons and use Navy air forces to support the Marine Corps mission.[2] That study recommended retaining those forces in the Marine Corps that are dedicated to close air support. It also expressed concerns about whether the Navy could provide the same level of support that dedicated Marine Corps squadrons would provide, given that the Marine Corps' aviation is an integral part of the Marine Corps' Air-Ground Task Force. However, altering pilot training could resolve some of those issues, as could changing the chain of command.

Yet Marine personnel argue that the close working relationship between the Marine Corps air and ground personnel results in safer and more responsive air support for ground troops. Marines are concerned about the availability of carrier-based aircraft. They are also likely to be concerned about whether Air Force aircraft would be available to them in some locations where airbases might be out of range of Marine Corps' operations.

2. Chairman of the Joint Chiefs of Staff, *Report on the Roles, Missions, and Functions of the Armed Forces of the United States* (February 1993), pp. III 17-18.

Option IA would purchase roughly the same number of planes as DoD plans for the missions it retains. As a result, it would produce fleets that are about the same age and shortfalls or overages of about the same size as the Administration plans through much of the period (see Figures 8 and 9). The option, though, purchases no Joint Strike Fighters for the Navy, whereas the Administration's plan would buy 180 of them through 2020 (the service plans to purchase a total of 300 planes). As a result, toward the end of the period, the Navy's smaller forces would age more and larger shortages would develop. Those shortages suggest that the Department of the Navy might need to consider continuing F/A-18 purchases or pursuing some other strategy.

Costs and Capability

The Congressional Budget Office estimated that a strike fighter designed only for the Air Force might cost about $15.6 billion to develop. That amount is more than CBO's estimate of the Air Force's share—about $10.7 billion—of the current program's development cost. Conversely, it would cost about a quarter less than CBO's estimate of development costs for the total JSF program ($21.5 billion). Because Air Force purchases made up almost 70 percent of the original program's purchases and because a single service design will avoid weight and size penalties for other service requirements, the Air Force-only Joint Strike Fighter might be about 2,000 pounds lighter. CBO also assumed that it would be smaller since the short takeoff vertical landing requirement is likely to increase the girth of the Joint Strike Fighter's fuselage.

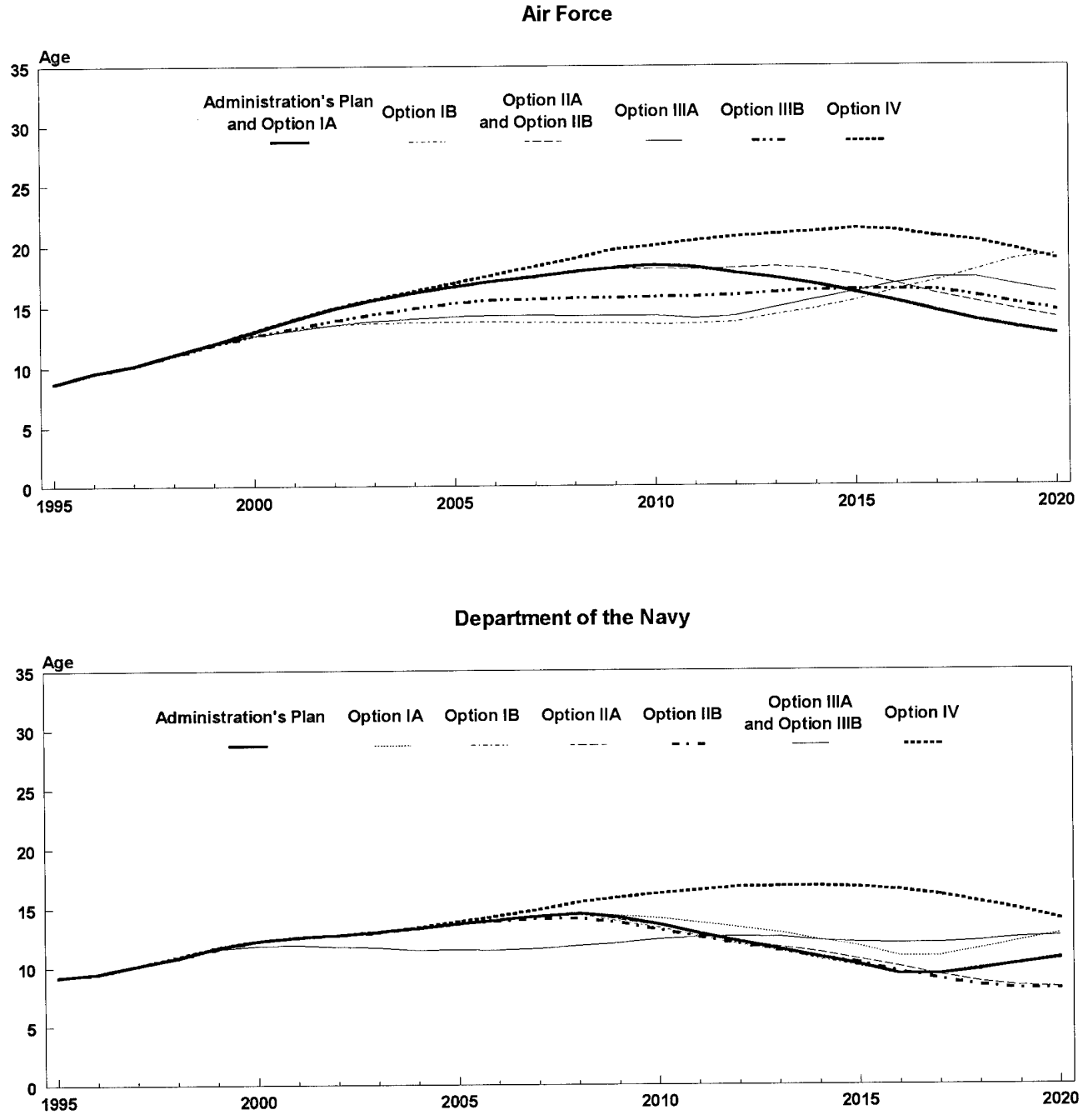
Table 11.
Average Annual Funding for the Administration's Plan and Options (In billions of 1997 dollars)

Alternative	Development		Procurement	
	1997-2001	2002-2020	1997-2001	2002-2020
Administration's Plan (CBO's Estimate)	2.3	0.9	4.7	11.9
Option IA: Set Priorities for Development (Emphasize Air Force Missions)	2.2	0.7	4.7	9.4
Option IB: Set Priorities for Development (Emphasize Naval Missions)	1.4	0.8	5.6	7.4
Option IIA: Build on Existing Development Efforts (with F-22N)	2.5	0.3	4.7	9.3
Option IIB: Build on Existing Development Efforts (with A/F-117X)	2.3	0.2	4.7	9.2
Option IIIA: Emphasize Current Generation Aircraft	1.7	1.1	5.3	7.9
Option IIIB: Emphasize Current Generation Aircraft with Modifications	2.1	1.1	4.9	8.3
Option IV: Make Proportional Cuts	2.3	0.9	4.7	6.3

SOURCE: Congressional Budget Office.

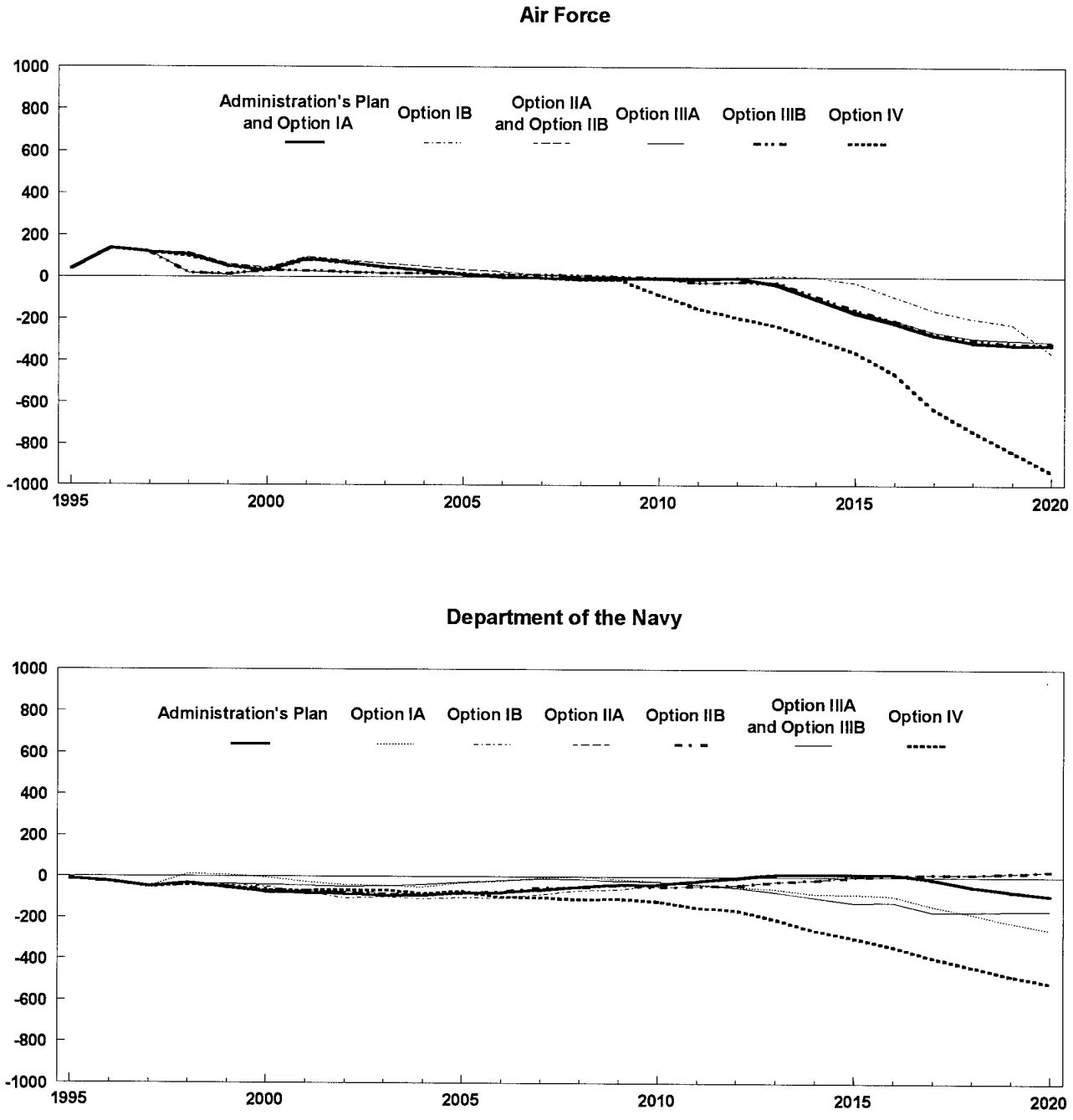
NOTE: Prices are based on cost-estimating relationships.

Figure 8.
Average Age of Air Force and Department of the Navy Fighter and Attack Aircraft Under Different Options, 1995-2020



SOURCE: Congressional Budget Office.

Figure 9.
Surpluses and Shortages of Air Force and Department of the Navy Fighter and Attack Aircraft Under Different Options, 1995-2020



SOURCE: Congressional Budget Office.

Because of savings from weight, size, and program complexity, CBO estimates that the unit procurement cost of the plane would be $65 million on average. That amount is only $2 million higher than CBO's estimate of the unit procurement price of the Air Force's version in the larger program, despite the loss of commonality with the 942 aircraft purchased for the other services.

Option 1A requires modestly more procurement funding than the other alternatives that CBO considered in this study, except for the Administration's plan (see Table 11 on page 59). The option is relatively expensive since it continues to purchase both the F-22 and the F/A-18E/F in the quantities planned by the Administration. Over the 2002-2020 period, the option would have an average annual procurement cost of about $9.4 billion, about $2.5 billion less than the Administration's plan, but still about half again the cost of past funding shares. Development costs for the option over the same period would average about $0.7 billion a year—about $0.2 billion less than the average for the Administration's plan.

Although Option IA is more expensive than other options, it would provide significantly more capability than today's fleets. Indeed, it might be acceptable even if air-to-air and surface-to-air threats increase in capability. The option's large purchases of F-22s and JSFs for the Air Force mean that by 2020 some 81 percent—the same as the Administration's plan—of the Air Force fighter and attack fleet will have lower signatures than today's aircraft. Moreover, in the case of the F-22, will be very stealthy if design goals are met. The option's large purchases of F/A-18E/Fs would also mean that about 91 percent of the Navy's fleet would have advanced planes (or 2 percentage points fewer than the Administration's plan). The Navy's fleet would have no highly stealthy planes, however, since the option cancels its JSF.

The option would lower the capability of Marine Corps' air forces significantly. That outcome may be tolerable if one expects that few conflicts involving only naval air forces will occur in the future or that naval aircraft operating from aircraft carriers will provide sufficient air support for the Marine Corps. Certainly, the Marine Corps' earlier concern that carriers would be drawn away from coastal operations to pursue other missions is less of an issue today than it was when defense planning scenarios involved a world war with the former Soviet Union.

Nonetheless, some policymakers and analysts will be more than a little concerned about leaving the Marine Corps with a limited number of aircraft to provide air support (only Marine Corps F/A-18s and its modest number of attack helicopters would perform that mission). Other policymakers and analysts will question whether the F/A-18E/F will have enough stealth to survive air-to-air and surface-to-air threats in the period beyond 2015. They will point out that because the option provides no development funds for this mission through 2020, the Navy will probably not field a new plane in large quantities for 10 to 20 years. Option IB addresses some of those concerns.

Option IB: Set Priorities for Tactical Aircraft Requirements—Emphasize Navy and Marine Corps

Some analysts argue that naval forces should receive the highest priority in today's strategic environment. Even if conflicts arose in locations where the United States lacks access to regional air bases, naval forces would be available. Some supporters of naval forces believe that the increased uncertainty about the location of future conflicts suggests that they are more likely to occur where the United States lacks access to the infrastructure needed to field ground-based U.S. air forces successfully. From that perspective, developing aircraft that improve the capabilities of the Navy's carrier-based air wings and the combat power of the Marine Corps' expeditionary forces is more important, than for the Air Force's land-based wings.

Therefore Option IB would develop planes to modernize those forces while deferring the modernization of land-based Air Force units. Specifically, the alternative develops a version of the Joint Strike Fighter for the Navy and Marine Corps. Based on an alternative that DoD planned to evaluate before the Bottom-Up Review, Option IB would develop only the short takeoff vertical landing version of the JSF and purchase it for both carrier air wings and Marine Corps squadrons.

In keeping with the theme of emphasizing naval forces, the alternative would also continue the interim development and purchase of the F/A-18E/F. Since the alternative would deemphasize land-based fighter and attack missions, it would cancel development of a Joint Strike Fighter version for the Air Force, though it hedges against uncertainty by purchasing almost 900 F-16Cs. Those purchases may provide enough planes to avoid substantial cuts in Air Force fighter and attack forces.

Option IB would cancel development of the F-22 as well. Such an action might be acceptable to those who feel that the modest capabilities of the fighters of potential enemies provide insufficient justification for purchasing a plane with the F-22's price and performance, and that DoD's fighter and attack dollars would be better spent on planes that focus more on ground attack. To wit, the alternative would continue purchases of the F-15E, a version of the Air Force fighter that emphasizes the interdiction mission, buying about 500 planes.

Risk and Balance

Option 1B would entail less development risk than the Administration's plan since it would develop fewer planes. It may have almost the same level of risk as Option 1A: the lower risks associated with canceling the F-22 development effort may offset the higher risk of developing a STOVL JSF.

Option 1B would purchase about 3,050 planes over the 1997-2020 period—almost 280 more planes than Option 1A. The reason is that requirements for planes under the option are assumed to remain at the levels in the Administration's plan rather than decreasing, as the previous option assumed. Option IB would also purchase a number of current generation aircraft—F-15s and F-16s—for the Air Force in larger quantities than the Administration's plan.

As a result, the Air Force structure would initially age more slowly than it would under the Administration's plan, not reaching 15 years of age until 2014 rather than 2002. After that, the fleet would age rapidly since no Joint Strike Fighters are being delivered. The Navy, which receives the same number of purchases in the same years as the Administration's plans, has the same aging patterns. It also has the same modest shortfalls.

Costs and Capabilities

Because Option IB would purchase much less expensive planes on average, it would be significantly less costly than either the Administration's plan or Option IA. It would have an average annual procurement cost of about $7.4 billion over the 2002-2020 period, about $4.5 billion less than the Administration's current plan. Thus, it should be easier to afford than the Administration's plan.

The Air Force would undoubtedly argue that the loss of the F-22 would increase combat losses in future conflicts and that canceling the program at this late stage would waste substantial funds. Canceling the F-22 could also cause a delay in the JSF program since that program depends on successfully developing the F-22's engine and some of the fighter's avionics.

The Air Force would also express serious concerns about the loss of a follow-on to the F-16, since it makes up such a large share of Air Force structure. Air Force leaders have expressed their doubts repeatedly about how well current generation planes will survive in the future. Should the F-16 prove to be obsolete because of the modernization of foreign weapons and be retired, the option could result in significantly reduced force structure.

The most serious problem with the option is that it leaves Air Force fleets with no stealthy fighter or attack aircraft by 2020 compared with 81 percent in the Administration's plan. That void could mean that U.S. fighter forces would be significantly less likely to survive in a highly threatening air-defense environment. The United States would depend heavily on the capability of the B-2 fleet and on stealthy JSFs in Navy and Marine Corps inventories if it had to bomb targets in such areas.

The Navy might also object to the option's assumption of purchasing short takeoff vertical landing aircraft for its aircraft carriers. Such aircraft may well have shorter ranges and smaller payloads than the Navy is currently envisioning for the JSF. Moreover, they may not be very stealthy.

Option IIA: Build on Existing Development Efforts

One obvious way to modernize future forces would be to build on existing development efforts. Excluding the Joint Strike Fighter program, the Department of Defense has three major development efforts under way for designing tactical fighters or attack helicopters: the F-22, F/A-18E/F, and RAH-66 (Comanche).[3] Option IIA would develop and produce versions of those systems to meet the JSF requirements, instead of entering into an independent design effort. Such an approach might enhance aircraft capability at less cost than stand-alone development efforts such as the JSF program. It would also increase the commonality among the services—one of the Clinton Administration's major goals for future tactical aircraft purchases—and do so sooner than the Administration's plan.

A Marinized Version of the F-22

Specifically, the option would purchase a marinized version of the F-22 for the Navy's requirement for stealthy strike. Actually, Air Force and Navy leaders had made a similar proposal in the mid-1980s—early in the F-22 program (then known as the Advanced Tactical Fighter—ATF—program).[4] At that time, a CBO publication suggested that a marinized ATF, a so-called Navalized ATF or NATF, would represent a significant challenge. But the services believed otherwise and argued that a Navalized Advanced Tactical Fighter was well within the realm of design feasibility.

Since no F-22N program currently exists, CBO estimated development and procurement costs. It estimated that the F-22N would have a procurement unit cost of $126 million, 17 percent more than CBO's estimate of the price of the F-22, and about 56 percent more than CBO's estimate of the cost of the Navy's version of the JSF. CBO also estimated that DoD would have to pay about $9.7 billion to develop the plane based on cost-estimating relationships (assuming a new airframe was developed and F-22 avionics and engines were integrated).

Purchasing the Navy's F/A-18E/F for the Air Force

The option would also purchase the Navy's F/A-18E/F for the Air Force's strike requirement, mirroring the successful F-4 program of the 1950s and 1960s. The F-4 Phantom fighter was originally developed for the Navy. But the Air Force purchased large quantities of F-4s, which then became the backbone of the Air Force's fighter fleet and was the F-15's predecessor. The Air Force probably purchased the F-4 in part because the Vietnam War increased fighter requirements. The Air Force made a number of modifications to the Navy's F-4 design, probably to make the planes more operable with other portions of the Air Force's tactical aircraft fleets and to add capabilities the Air Force wanted. Yet the program still represents one of the few successful joint ones to produce fighter or attack aircraft. A number of other countries also purchased F-4s, and in fact they can still be found in many foreign fighter fleets.

The F/A-18's manufacturer, McDonnell Douglas, might be able to reduce the F/A-18E/F's weight and therefore cost. But the Congressional Budget Office assumes that the Air Force would purchase the same aircraft the Navy intends to buy, thus ensuring maximum commonality. If the Air Force did not make any design changes, it would not need to spend money on development costs for the F/A-18. CBO assumes that most of the savings from canceling development of the Joint Strike Fighter would be used to purchase aircraft and to decrease funding for tactical aviation in the long term. But some of those savings would also need to be reallocated to pay the costs of developing the F-22N.

Develop a Marinized Version of the Comanche

Option IIA would not develop a fixed-wing replacement for the AV-8B for the Marine Corps. Rather it would develop a marinized version of the stealthy Comanche armed reconnaissance helicopter, being developed for Army scout and light attack roles, and would

3. Army plans also include the Longbow Apache program, an extensive modification of its current attack helicopter, the AH-64 Apache.

4. Congressional Budget Office, *Naval Combat Aircraft: Issues and Options* (November 1987), pp. 60-63.

purchase them to provide support for Marine Corps ground troops.[5] It also would purchase additional F/A-18E/Fs for the Marine Corps fighter squadrons that are currently equipped with earlier model F/A-18s.

Risks and Balance

Option IIA should entail less risk than the Administration's current plans for modernizing tactical aircraft, since the designs that are produced are farther along in the development process than they are for the Joint Strike Fighter. Similarly, the strategy in Option IIA might pose somewhat less of a risk of design failure than would the first option. Option IA would build the same number of new planes, but it would continue to develop the totally new Joint Strike Fighter for the Air Force rather than producing marinized versions of existing development efforts such as the F-22 and Comanche. The challenges in developing aircraft for the rest of the carrier-based fleet would be the same since both options pursue the F/A-18E/F upgrade.

Developing a version of the Army's Comanche attack helicopter to operate off of amphibious ships would require developing folding rotor blades and an added mechanism to stop them from rotating. Similar changes have been made in many earlier design programs, including the Navy's SH-60B Seahawk helicopter, a sea-going derivative of the Army's UH-60 Blackhawk. But retaining stealth in the RAH-66 might complicate designing a marinized version. The option could also add to the number of types of aircraft that the Marine Corps operates.

As with both versions of Option I, the services are apt to view the approach in this option with considerable skepticism. Since the Marine Corps needs to keep its forces light to make them easier to transport rapidly, it uses fixed-wing aircraft such as the Harrier to provide firepower. In contrast, heavy Army forces rely more extensively on self-propelled howitzers and tanks. Attack helicopters, which carry smaller payloads than the Harrier—about 3,000 pounds compared with about 6,000 pounds—would provide less firepower. The Marines rely on air support to lay down heavy barrage fires against enemy targets, particularly counterbattery fire, and might be concerned about reducing available firepower. Marines also express concerns about whether helicopters—which typically do not fly over enemy forces—would be able to hit targets behind enemy lines thereby affecting battle outcomes.

Added purchases of F/A-18E/F aircraft for Marine Corps fighter squadrons might alleviate some of those concerns. The Navy expects the new model to be able to carry a heavier payload than the aircraft currently in the fleet.

Marine Corps personnel might also worry about whether the slower flight speeds of helicopters would make them less responsive to requests from Marine Corps ground forces for air support. Planes performing close air support in the Marine Corps are expected to respond rapidly to a call for help. According to informal conversations with Marine Corps personnel, aircraft performing the close air-support mission should be able to take off from shipboard and within 20 minutes bomb enemy forces at distances that could be as great as 100 nautical miles or more.

Option IIA would not meet that requirement, since helicopters fly at much slower speeds than even the relatively slow Harrier. Harriers, which can fly at 550 knots—at least for short distances—can easily meet the requirement. The Comanche, which is expected to fly at about 175 knots would take about 30 minutes to fly 100 nautical miles—about 50 percent more than the time that the Marine Corps' requirement calls for.

However, helicopters might be more responsive than fixed-wing aircraft if they accompanied ground forces, as is the practice today for the Marine Corps' attack helicopter fleet. Moreover, the Comanche is expected to offer some capabilities that the Marine Corps might find useful, including a stealthy design that might make it more able to survive in a highly threatening environment. In addition, if major concerns arise about reducing Marine Corps firepower, the Marines might be able to purchase and field larger numbers of helicopters than fixed-wing aircraft, since helicopters are much less expensive. Even the Comanche, which is likely to be very expensive for an attack helicopter, might—if bought on the schedule CBO assumes—cost about $25 million on average, a little more than a third of CBO's

5. The Comanche, along with the Longbow Apache, an extensive modification of the Army's current attack helicopter, are discussed in Congressional Budget Office, *An Analysis of U.S. Army Helicopter Programs* (December 1995).

estimate of the price the Marines might have to pay for the Joint Strike Fighter and about $5 million less than the cost of modifying existing Harriers.

CBO did not explicitly cost out an option that purchases the AH-64D, the Apache Longbow, a modification to the Apache that the Army is buying for its attack helicopter fleet. But AH-64Ds would be available sooner than the Comanche, would be somewhat cheaper, and might provide more firepower. The Apache lacks, however, the Comanche's stealth design.

Option IIA produces a slightly older fleet for the Air Force than the Administration's plan, since it purchases about 100 fewer planes for that service. The option buys almost 80 more planes for the Navy and Marine Corps and so, in the long-term, decreases fleet ages slightly and eliminates shortfalls. The lower design risk of the alternate development programs might also make them less likely to fall behind schedule than would the Joint Strike Fighter, though some analysts feel that it could be more challenging to develop an F-22N than the JSF.

Costs and Capability

Option IIA is less costly than the Administration's plan, requiring average annual procurement funding of about $9.3 billion over the 2002-2020 period—or about four-fifths of the funding needed for the Administration's plan. But by any reasonable standard it is still very expensive. The Department of Defense would need to spend about 50 percent more on purchasing fighter aircraft than it has on average in the past. The option might therefore be difficult to afford if DoD finds it has too many other programs competing for resources.

The F/A-18E/F has a longer range and larger payload than those associated with the Air Force requirements for the Joint Strike Fighter. As a result, Option IIA might produce an Air Force fleet that is more capable in some ways than a fleet with JSFs. The F/A-18E/F might also meet some of the Air Force's stealth requirements, though that is the subject of some debate.[6] Even though some analysts suggest that the F/A-18's stealth attributes may be somewhat limited, the Air Force's stealth requirements for the JSF are less stringent than those of the Navy. The Navy claims that the F/A-18E/F is sufficiently stealthy to survive under any scenario the United States might face, at least through 2015.[7] By replacing the single engine F-16 with the twin engine F/A-18, the option could result in a higher operating cost than the Administration's plan.

Option IIA could also produce a more capable naval fleet, since the F-22N would outperform the JSF in some ways. Specifically, F-22Ns might very well have more sophisticated avionics and be able to fly supersonically without using an afterburner. The F-22's level of stealth may also meet the Navy's desire for very stealthy aircraft. Still the basic plane can carry only two 1,000-pound precision-guided weapons internally and so would not meet the Navy's requirement to carry 2,000-pound bombs. (Since CBO's estimate for development assumes that DoD develops a new airframe for the Navy, the plane might be sized to carry larger bombs.) Improvements in the technology of explosives could make the need for such large warheads obsolete, but the Navy may have factored those improvements into its judgment about that requirement. In addition, the F-22 probably offers more fighter capability than the Navy needs—and at a hefty price. Finally, Navy personnel have reservations about the F-22's size, weight, and the feasibility of designing a version of the plane that can take off from and land on a carrier. Decisionmakers might prefer to purchase a stealthy plane, designed for the attack mission, that might address some of those concerns.

Option IIB: Build on Existing Development Efforts, but Purchase an A/F-117X Instead of the F-22N

Doubts about the relatively limited long-range bombing capabilities of the Navy's planned carrier air wings may have led Congressional leaders to suggest that DoD evaluate other alternatives, including a version of the Air Force's stealthy F-117. In its report on the fiscal

6. General Accounting Office, *F/A-18E/F Will Provide Marginal Operational Improvement at High Cost*, p. 37.

7. Office of Naval Intelligence, *Worldwide Challenges to Naval Strike Warfare* (1996). One would hope that the F/A-18E/F, which is scheduled to remain in production until 2015, would continue to survive until the end of its service life, around 2035 or later.

year 1996 budget request, the Senate Armed Services Committee directed the Navy to evaluate such an option. The authorization conference agreed to such an evaluation, although it authorized very few funds, and subsequent language in the appropriation bill eliminated the requirement altogether.

The Skunk Works, the part of the Lockheed Martin company that designed and produced the F-117, one of the Air Force's stars in the war with Iraq, proposed a version of the plane—the A/F-117X—that would operate off aircraft carriers. Although the plane would fly subsonically, the proposed design was to possess more range and a greater payload than the Navy's JSF version. It would also be likely to have a larger payload and longer range than the F-22N. The Lockheed Martin proposal promised a plane that could carry two 2,000-pound weapons on a combat mission of more than 800 nautical miles—about 200 miles farther than the Navy's minimum requirement for the JSF. The F-117 version would also be likely to meet the Navy's more stringent stealth requirements and could carry even higher payloads on shorter missions. Moreover, an A/F-117X would probably be cheaper both to develop and purchase than the F-22 version.

CBO estimates that developing the Navy F-117 could cost about $7.7 billion—in short, about $2 billion less than the F-22N. If 300 A/F-117Xs were bought, the same number of planes as the Navy's share of the JSF program, the unit procurement cost of the fighter—about $106 million—would also be lower than the F-22N, though it is about 30 percent higher than the potential price of the Navy's Joint Strike Fighter.

Option III: Purchase Aircraft That Are Now in Production

Option III would decrease or defer modernization efforts, while attempting to preserve force structure. To accomplish that, the option assumes that DoD spends some of the money saved by canceling, deferring, or scaling back modernization plans to purchase more of today's aircraft so the services can maintain current force levels and avoid aging fleets. Such an alternative might be appealing if one believed that the United States might need relatively large numbers of forces to fight in several arenas and that the forces of potential enemies were unlikely to be extensively modernized and therefore posed little more threat than they do today.

Specifically, Option III would scale the Joint Strike Fighter program back to the Administration's original concept of having the program explore new technologies and defer JSF purchases for seven years. Such a delay in developing the Joint Strike Fighter would permit DoD to evaluate its needs for new aircraft—perhaps with better knowledge of how potential enemies were modernizing their forces. If it appeared that little modernization was likely, further deferrals of development might be acceptable.

Option III would also not begin to increase purchases of F-22s until 2001, and would purchase only 240 of the planes, slightly more than half the number the Air Force wants, but enough aircraft to field two tactical air wings. Such a "silver bullet" buy—small purchases of highly capable but expensive weapons—would permit DoD to learn all the lessons involved in developing and producing F-22s at a lower total cost. Also, the decrease in fighter production might be tolerable if potential foes are unlikely to have sophisticated fighter forces. The delay would permit the program to complete a larger portion of its testing before entering its full rate of production, thereby addressing Congressional concerns about concurrency. It also would give the Air Force a few more years to assess its needs for the fighter.

In addition, Option III would cancel developing and producing the F/A-18E/F, but would continue to purchase F/A-18C/D aircraft. Since the Navy has modest shortages in its fighter fleet, the option would use some of the funds freed by canceling the E/F to add 274 F/A-18C/Ds to the budget during the 1997-2001 period. That would be 112 more than the number of F/A-18E/Fs planned for the same period. The option also assumes that McDonnell Douglas would produce 60 additional AV-8Bs to provide air support for U.S. Marine Corps ground forces in the long interval before JSF production. According to McDonnell Douglas, adding newly produced AV-8Bs should be possible without substantially changing the production base since the ongoing remanufacture of the AV-8 is such an extensive modification.

This option mirrors recent Congressional actions. The Congress added money to purchase six F-15Es and six F-16s for the Air Force in 1996. It also funded six more F/A-18C/D aircraft for the Navy. In the fiscal year 1997 budget, the Congress added funding for two additional F-15s and two more F-16s (above the Administration's request for four of each) and also added money for six F/A-18C/D aircraft.

CBO developed two versions of Option III. The first of the versions buys the latest model of the F-16. For Option IIIA, CBO assumes that F-16 production would increase to 60 planes per year by 1999. The option purchases a total of 768 F-16s to stave off the need for reducing forces until the middle of the second decade of the 21st century, when CBO assumes that DoD might begin purchasing more advanced aircraft.

A second version (Option IIIB) assumes that DoD develops and purchases an improved F-16, the so-called F-16 multistaged improvement program (MSIP). The F-16 MSIP would have more sophisticated avionics and could carry a wider variety of weapons, but it would still lack much of the enhanced capability that the Air Force will seek in a new fighter design. It mirrors an option the Air Force considered in the early stages of the now canceled multirole fighter program. A quantity of 768 F-16s would be bought, the same amount as in Option IIIA. Option IIIB would purchase fewer F-16s during the 1997-2001 period because of the need for near-term development funds. But prices for the two versions of the F-16 would differ. The more advanced F-16 would be more costly with a procurement unit cost of about $38 million compared with $30 million for the current version. Moreover, CBO assumed that it would cost an additional $2 billion to develop the improved version.

Both versions of Option III would also purchase 214 additional F-15Es to compensate in part for the reduction in F-22 fighters and partially to add to DoD's medium-range attack fleet. Planes that can carry large payloads relatively long distances, such as the F-15E, might be particularly useful if one assumes that the United States could easily engage in an extensive air campaign or if one places a relatively high emphasis on strategic targets located some distance from U.S. bases. Nonstealthy F-15Es might also be useful if new precision-guided munitions provide more standoff attack capability that would permit conventional aircraft to fire at targets from outside the range of surface-to-air weapons.

CBO assumed that the savings from slowing F-22 purchases could be used to purchase F-15Es during the 1998-2001 period. Recent announcements by the Air Force suggest that some of those savings might not materialize. On December 19, 1996, the Air Force wrote the Congress to announce changes to the F-22 program that extend engineering and manufacturing development and slow increases in annual production.[8] Cost increases in both development and production may have led to the restructuring. If the option's savings were estimated against the revised plan, fewer F-15Es could be purchased during the 1998-2001 period than assumed here.

Risk and Balance

Options IIIA and IIIB probably offer about the same risk of developmental failure as both versions of Option II. The two versions of Option III develop the same number of planes, though those developed are more complex efforts. (The options also avoid the modest risk associated with marinizing the Comanche.) The F/A-18E/F—developed in Options IIA and IIB but not in either version of Option III—is probably the least challenging of the Administration's efforts at development. But both versions of Option III might reduce some of that risk since they defer beginning development for the F-22 and the Joint Strike Fighter. Developing the F-16 MSIP probably adds only modestly to development risk.

Because they purchase more planes earlier, both versions of Option III defer some of the aging of aircraft under the Administration's plan. Also, the additional near-term purchases of 112 F/A-18s should decrease the shortfalls that the Department of the Navy would experience under the Administration's plans. Thus, the options might avoid some of the risks of reductions in force levels that are inherent in the Administration's plan. They also provide larger inventory hedges against the possibility that fighters might not last as long as the services currently estimate. In the

8. Letter to Representative Curt Weldon, Chairman of the Military Research and Development Subcommittee of the House National Security Committee, from Arthur L. Money, Assistant Secretary of the Air Force (Acquisition), December 19, 1996.

longer term—toward 2020—both options would result in older fleets than would the Administration's plan. The Navy's fleet would also be smaller.

Costs and Capabilities

Both versions of Option III, compared with the Administration's plan, result in significant savings in the long term. Neither option produces near-term savings, however, since CBO assumed that purchases of aircraft currently in the fleet would offset savings from delays in modernizing.

In the longer run, Option IIIA produces substantial savings during the 2002-2020 time period. Its average annual procurement cost of $7.9 billion is about $4 billion less than CBO's estimate of the price of the Administration's plan. It results, though, in funding that is about 25 percent more than that of historical shares. Option IIIB, which purchases a modified F-16, would have average annual procurement costs of $8.3 billion, $0.4 billion more than Option IIIA, the option that purchases the basic aircraft.

Increases in development costs during the 2002-2020 period would marginally offset savings in procurement under both options. Deferring the start of developing the JSF until 2003, compared with 1997 in the Administration's plan, means that more of the program's development costs would occur during those decades. As a result, average annual development funding would rise by about $0.2 billion for both versions of the option during that period. (Development funding for the F-16 multistaged improvement program was assumed to have already been spent during the 1997-2001 period.)

Options IIIA and IIIB decrease and defer peak annual funding requirements, since they eliminate the overlap between aircraft purchases. Despite that effect, even Option IIIA, the cheaper of the two versions, still has a bow wave. In 2017, when purchases of the Joint Strike Fighter are assumed to reach peak rates, it would require spending almost $13 billion on procurement, about $6 billion less than peak Administration funding. Yet that amount would be more than what could be available if other pressures are placed on the budget.

On the one hand, the options offer more qualitative capability than today's fleet. The option's proposed purchases of F-22s and JSFs would mean that by 2020 the United States could field more than tenfold the number of stealthy fighters that it can field today. Moreover, the added F-15E purchases would increase near-term strike capability. Further, the added purchases of F/A-18C/Ds would mean that both the Navy and Marine Corps would have aircraft for their fighter squadrons.

On the other hand, neither option meets the services' requirements for improving capability, primarily in the low-observables area. The services would argue that the options would leave their fighter fleets vulnerable to advances in aircraft and surface-to-air missile capabilities. The Air Force has expressed concerns about the effectiveness of even the top-of-the-line F-15 in potential conflicts. The Navy argues that eliminating the E/F model while purchasing C/Ds leaves them with a plane that has too short a range to be useful in many contingencies and that cannot land on a carrier deck with its full complement of weapons. The Navy would also probably maintain that the loss of the E/F model's reduced visibility would make its aircraft fleet more vulnerable to air-to-air and surface-to-air threats. Finally, the Marine Corps would find the modest additional purchases of the Harrier insufficient compensation for the seven-year delay in deliveries of the advanced short takeoff vertical landing version of the Joint Strike Fighter.

For all of those reasons, the Congress and future Administrations might want to pursue courses illustrated by those options above that pay for more modernization. But those options require allocating a larger share of future budgets to tactical aircraft than has been spent to date. If future Administrations find that other competitors for defense dollars cause them to hold fighter funding to past shares, or if defense spending is itself reduced further, cuts to tactical aircraft spending might be needed.

Option IV: Make Proportional Cuts to All Programs and Accept Force Cuts

Option IV is the only option the Congressional Budget Office considered that actually cuts the funding for tactical aircraft to the levels associated with historical shares. It does so by using an approach that is a common outcome of the budget process: the pain would be shared equally by making proportional cuts to all programs rather than killing any single program outright. Realistically, some programs would probably expire as the result of such a strategy, but they could take a long time and large public expenditure before they do.

Such a strategy might also be consistent with a choice to explore a number of design efforts rather than purchasing large numbers of aircraft to preserve force structure or defer aging. The Clinton Administration proposed to develop weapon systems and produce them in limited quantities. Such proposals could result in large numbers of development programs with procurement largely limited to what is needed to explore production issues.

Sizable cuts in force would, however, be the outcome of such a choice. First, the relatively larger sums spent on funding for development could come out of procurement funds. To compound the problem, purchases of small numbers of planes increase the procurement cost of the average aircraft. So not only do fewer dollars go to purchases, but those that do purchase less.

Risk and Balance

The design risk in Option IV should equal that of the Administration's plan, since it develops all of the planes included in that plan. Therefore, concerns about development in the Administration's plan would also apply to this option.

Because this alternative would purchase only about half the number of planes that the Administration's plan procures—1,702 compared with 3,436—the option results in a smaller and older force. By 2015, fighter requirements would exceed inventories by about 650 planes. The Navy would be short about 300 planes, and the Air Force would have a deficit of 350 planes. In 2020, after five more years during which retirements exceed purchases, shortages would total about 510 and 930 planes for the Navy and Air Force, respectively. Under the Administration's plan, such shortages would amount to about 90 planes for the Navy and 320 planes for the Air Force by 2020. In 2020, average fleet ages under Option IV would also be high—about 14 years for the Navy and 19 years for the Air Force.

Taken together, those results indicate that a choice to pursue development at the expense of purchases could result in very small fleet sizes. It would be unrealistic to assume that DoD and the services could retain aircraft in the fleet longer to make up shortages, since even under the Administration's current plans the fleet will reach unprecedented ages. If forces were reduced to eliminate those shortages, the Air Force might have 11 wings—about 55 percent of its current force size. Navy and Marine Corps forces would experience similar reductions.

Cost and Capability

As suggested above, CBO intentionally structured this option to characterize the purchases that might be made if DoD spends no larger a share of the budget on fighters than it has in the past or attempts to pursue all currently envisioned development efforts. At about $6.3 billion on average over the 2002-2020 period, the procurement price of Option IV equals the amount associated with previous shares. Option IV's average procurement cost is about 53 percent of the funding in the Administration's plan.

Those results demonstrate the penalty paid for reducing purchases. Although average annual procurement funding for the 2002-2020 period is cut by less than half, quantities purchased during the same period are reduced by more than half. In fact, the average purchase price of planes under this option is more than 10 percent higher than it would be under the Administration's plan, since aircraft producers do not become as efficient at production if they make smaller numbers of planes.

However, the actual adverse impact on aircraft prices of a strategy employing proportional cuts could be even greater. The Congressional Budget Office's estimate assumes that aircraft producers build and equip facilities that are sized to production rates. DoD's past experience is that producers usually build facilities that are sized to planned rates that never materialize. That phenomenon occurs for several reasons, including optimism about the availability of future funding and about future aircraft prices. CBO is unable to estimate the cost burden if future plans prove to be as unrealistic as past plans. But prices could be higher than those CBO assumed if DoD equips facilities to produce more planes than it orders.

Option IV would probably have significantly less combat capability than any of the other alternatives, even though the individual planes it purchases may be more capable than alternatives that pursue less modernization. Still, the smaller force structure associated with the alternative—55 percent to 65 percent of current levels—might be acceptable if one expected to require forces to fight only in one regional conflict. In addition, the more capable, though smaller, forces might provide sufficient hedges against improvements in enemy defenses.

Conversely, Option IV provides less capability for the cost than a more selective development effort might provide. In addition to its inefficiency, the option's small forces would provide little reserve for fighting a second conflict, should one emerge. Finally, if DoD was to reduce the number of its forces that low, rebuilding would be a formidable task if a more challenging threat emerged on the horizon.

Appendixes

Appendix A

Stealth and Fighter and Attack Aircraft Design

Stealth is a term the Department of Defense (DoD) uses to describe reduced visibility to enemy sensors. Reduced visibility is one of the factors that determines whether an aircraft, missile, or weapon will survive to carry out its mission. Many people think of stealth in terms of reducing visibility to enemy radars. But DoD also uses the term to describe reducing a platform's visibility to infrared (heat) sensors, acoustic (sound) sensors, to human eyes and ears, and to systems that pick up an aircraft's electronic emissions.

Nonetheless, much of the design effort to make a weapon system stealthy focuses on reducing its radar cross section—that is, the size of its signature to enemy radars. The radar cross section is critical since radars represent the most likely detection method for integrated air defense systems as well as for most individual air defense weapons. (When compared with most other kinds of sensors, radars can provide more information about and more accuracy on the location of targets, and can operate in adverse weather and atmospheric conditions.) Smaller signatures do not mean that planes are completely invisible to radar, but rather that enemy radars will be able to detect aircraft only at shorter ranges. Radar systems that are less capable, such as those on small mobile systems—surface-to-air missiles and antiaircraft artillery—may detect stealthy targets at such a reduced range that effective tracking and subsequent engagement may be out of the question.

Moreover, the signatures of highly stealthy aircraft, being equivalent to those of birds and insects, may fall within the "noise" level of some radars. Such radars may be set to decrease false detection rates and result in an inability to see objects with small signatures. More sophisticated radar-detection systems may have the capability to overcome that problem to some degree. Thus, in the future, they may be able to see stealthy targets, though it would still be at much shorter ranges than nonstealthy planes and missiles.

Shorter detection ranges open corridors in air-defense networks for stealth aircraft. That ability permits the U.S. military to develop routes and tactics that will allow aircraft to attack targets that more conventional planes might find difficult and risky to reach. Shortening the range of radar may mean that operators of surface-based, antiaircraft systems cannot take advantage of their missile's full range—that is, their engagement range can be reduced to a fraction of that for a conventional aircraft target. Moreover, with late detections, the threat systems have less reaction time. Given the high speeds (perhaps 500 to 1,000 or more miles per hour—8 to 17 miles per minute) at which fighter aircraft may fly in highly threatening environments, missile operators would have very little time to fire at a stealthy target that might not be detected until within 10 to 20 miles of the surface-to-air system. Those shorter ranges permit a stealthy aircraft equipped to attack antiaircraft systems to launch its weapons and subsequently

avoid the system's sharply reduced engagement zone. Also, antiaircraft systems will be much less likely to be able to take multiple shots at stealthy planes. Finally, stealthy aircraft add an element of surprise to air attacks and can fly within attack ranges of some targets without being detected.

Radar range is also critical when interceptors are guided to their target by ground-based radar. Smaller signatures decrease the ground-controlled intercept radar range and thus track time. That effect delays or interrupts steering commands to enemy fighters. As a result, getting the threat interceptor to the correct location for a successful missile launch is difficult. Another problem for the enemy is that small airborne radars (when compared with ground-based radars) find it difficult to detect targets unless they are pointed in the right direction or the targets are close. Enemy fighters may spot stealthy planes too late. Thus, they may be unable to attack stealthy planes or escape from them. (The stealthy aircraft may have launched its weapons already). Moreover, since many surface-to-air and air-to-air missiles use radar returns for tracking a target to the intercept point, smaller signatures may also decrease the capability of enemy missiles.

Very small signatures might make enemy missiles more vulnerable to countermeasures carried by the stealthy plane. Countermeasures include chaff—a cloud of metallic bits designed to fall in a way that creates a tempting signature—and decoys, which are towed electronic emitters that create an electronic signature for enemy missiles to home in on. A stealthy plane's signature is smaller than that of a chaff cloud or a towed emitter. Indeed, a stealthy vehicle has fewer requirements for the high-cost areas of countermeasure power and complexity. That is the result of the basic physics involved in protecting an aircraft with a much smaller signature. It applies to both "on board" countermeasures and "off board," such as that provided by standoff jamming platforms. For all of those reasons, defense mission planners would prefer to have some stealthy platforms early in the war to defeat enemy air defenses and attack high-value targets that are heavily defended.

The way a radar beam is reflected from the surface of an object determines radar signatures.[1] Consider the analogy of a person shining a flashlight at a mirror to take just one example. If the flashlight is held at a 90 degree angle to the mirror the light bounces back directly and the reflection is the greatest. If the light hits the mirror at an oblique angle, it bounces away from the source of the light. A concave mirror reflects light back to the light's source from a number of angles, whereas a convex mirror would deflect light away from the source. Among the best radar returns (worst from a stealth perspective) is that produced by the dish-shaped antenna of a radar receiver. The worst radar returns are from those objects that fragment the radar beam, cause it to bounce off at a different angle, or diffuse the radar returns.

Adding film to the mirror, which absorbs some of the light, reduces the amount of light that is reflected back as well. A flat black paint would preclude any visible light from being reflected back to the observer.

Designers of stealthy weapon systems try to capitalize on those simple physical principles by building systems whose shapes deflect the radar returns. Stealth designs may include faceted or rounded surfaces to deflect or diffuse radar returns. Since weapons carried externally are likely to increase radar signatures (by having corners where they are attached to the plane or themselves having large radar signatures), highly stealthy aircraft carry their weapons internally.

In addition, designers employ radar-absorbing materials (similar to painting the mirror) to reduce the return. Designers must also mask concave apertures such as cockpits, engine intakes, and exhaust nozzles. Finally, stealthy designs may also reduce or disperse engine exhaust to decrease the intensity of the heat of the exhaust plume and, thus, its infra-red signatures.

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1. The radar return also depends on a number of other factors illustrated in the radar equation: for a discussion of radars, radar cross sections, detection ranges, and stealth, see Merrill L. Skolnik, *Introduction to Radar Systems* (New York: McGraw-Hill Publishing Company, 1980), pp. 33-65 and 553. An extremely helpful discussion of the design issues in reducing radar cross sections is provided in Eugene F. Knott, John F. Shaeffer, and Michael T. Tuley, *Radar Cross Section* (Boston, Mass.: Artech House, 1993), which discusses shaping and radar-absorbing materials. Research notes from a Georgia Tech Research Institute course by Michael T. Tuley entitled, "Radar Cross Section Reduction" were also particularly valuable.

Table A-1.
Selected Objects and Their Visibility to Radar

Object	Radar Cross Section		SAM Tracking Range (Nautical miles)	
	In Decibels	In Square Meters	Target at 500 Feet	Target at 15,000 Feet
Large Transport Aircraft	20	100.0	40[a]	150
Conventional Fighter Plane	10	10.0	40[a]	125
B-1B Bomber	0	1.0	40[a]	75
Cruise Missile	-10	0.1	30	50
Large Bird	-20	0.01	20	30
Insect	-30	0.001	10	20

SOURCE: Congressional Budget Office based on a presentation from Lockheed Martin on the Value of Stealth.

NOTE: SAM = surface-to-air missile.

a. Limited to line of sight.

The two strategies of coatings and masking may be used to reduce some aspects of the signature of a conventionally designed aircraft. But to achieve extremely small signatures, aircraft designers are driven to new designs that weigh shaping considerations—hidden engines, carrying weapons internally, and other attributes of stealth design—with performance and other mission requirements.

Measuring a Plane's Signature

The size of a plane's signature is expressed in several ways (see Table A-1). One is the radar cross section, which is expressed in square meters.[2] Along with square meters (m^2), the stealth and radar communities often use decibels (db). That is a logarithmic measure of the strength of the signal return relative to some reference level, conceptually similar to the scale used to describe the intensity of sound.[3]

DoD describes a continuum of stealth for aircraft that starts with conventional aircraft, goes to near low observable, to low observable, and then to very low observable. Those terms have no unclassified definition, and some analysts have suggested that the Air Force and the Navy use them differently, and that furthermore some contractors, attempting unclassified explanations of the level of stealth of their weapons, may also use those designations loosely.

Among the few unclassified discussions by DoD personnel on the meaning of the very low observable designation is the testimony of General Larry D. Welch—a former Air Force Chief of Staff—who was discussing the B-2 bomber's signature in an unclassified forum. General Welch suggested that a very low observable plane, such as the B-2, might produce a signature equivalent to that of an insect (see Table A-1 for

2. The measurement of a single radar cross section is a great simplification of a plane's visibility to radar, since the signature will vary depending on the angle of the radar to the plane. For example a plane that has a low signature from the front might have a large signature if viewed from the side, back, top, or bottom.

3. Paul A. Tipler, *Physics* (New York: Worth Publishers, Inc., 1976), p. 525.

decibel and square meter radar cross section measurements for a variety of flying objects, including insects).

According to a briefing on the value of stealth prepared by the Lockheed Martin Corporation, an unspecified insect might have a radar cross section of .001 m^2.[4] The same briefing suggests that a conventional fighter could have a signature of 10 m^2, or much larger than the insect's signature. Low observable objects presumably would fall somewhere in between. The B-1B bomber, which may incorporate some technology for reducing signatures, may achieve a radar cross section of 1 m^2, and a cruise missile could have a radar cross section of 0.1 m^2.

The dramatic reductions in signature to reach the low observable designation or very low observable designation are necessary if DoD wishes to reduce radar ranges sharply—the result of the relationship between radar range and target signature. The form of the radar equation that describes that relationship is:

$$R_{max} = [P_t G^2 \lambda^2 RCS/(4\pi)^3 P_{min}]^{1/4}$$

where; R_{max} = the maximum radar range; P_t = the transmittal power of the radar signal; G = the gain of the antenna; λ = the wave length; RCS = the radar cross section of the target; and P_{min} = the power of the minimum detectable signal.[5] Since the variable of the range in the equation is raised to the fourth power, other variables have to be reduced significantly to decrease radar ranges. For example, the radar cross section would have to be reduced by 12 db (a 16-fold reduction in meters squared) to reduce a radar range by half. Radar power would need to increase by 16 times to recapture the range—an expensive proposition and one that may actually place the radar at more risk of attack.

Although stealth has obvious advantages, it also has disadvantages, particularly if the weapon is to fall into the very low observable category: stealthy designs are more costly, probably carry smaller payloads than conventional aircraft, and may have shorter ranges or be less agile in flight. Obtaining a very low observable level of stealth while carrying weapons externally may be difficult and perhaps impossible. For one thing, the weapons themselves would have to be stealthy, which would increase their cost. Also, weapons would need to be carried conformally—that is, in ways that do not alter the shape of the aircraft a great deal—which probably would involve designing and purchasing a stealthy pod.

Internal carriage creates the need for a larger fuselage, and it reduces aircraft payloads, unless the designers choose unconventional shapes—such as the bat wing shape of the B-2 or the faceted F-117. (Designers also use internal carriage for long-range aircraft since weapons carried internally create less drag.) Such unconventional designs can also, however, have cost penalties. Stealth aircraft typically contain more exotic materials than conventional planes. Coatings add weight and labor. Production facilities have to be more secure—entailing, among many changes, more secure buildings and special computers as well as more guards. Moreover, production personnel must be cleared at higher levels. Avionics on stealthy planes may be more sophisticated as well. In addition, maintenance may be more difficult. For example, even dents in the smooth coating of a stealthy plane could increase its signature. In short, all of those factors can reduce other elements of capability and increase costs.

One other issue is whether stealth is perishable. Consider another analogy: developing technology for fighting wars is an ongoing game of cat and mouse. If the mouse becomes quieter and learns to forage at night, the cat develops better hearing and learns to see in the dark. Some defense experts have suggested that improvements in enemy sensors may take away—or at least decrease—the advantages of stealth in the future.[6]

One method of defeating stealth would be to develop higher-powered radars. A very high-power radar could give antiaircraft systems back the range lost as a result of reducing target signatures. Looking back at

4. See Lockheed Corporation briefing, *The Value of Stealth* (May 1994) for a useful unclassified discussion of stealth technology. The briefing refers to an article by William O'Neil, "Don't Give Up On the Ship," U.S. Naval Institute, *Proceedings* (January 1991), p. 48. That article provided data on the radar cross section of various objects. Presumably the type of insect matters and a bee would have a larger radar cross section than a gnat, but the analogy gives a useful idea of the order of magnitude reductions that DoD expects from stealth technology.

5. See Knott, Shaefer, and Tuley, *Radar Cross Section*, p. 46. That is a simplified equation.

6. For a discussion of stealth and possible alternatives or countermeasures, see Department of the Navy, Office of Naval Intelligence *Worldwide Challenges to Naval Strike Warfare* (January 1996).

the radar equation, however, one finds that the power of the transmitter needs to increase dramatically to make major increases in tracking or detection ranges. Such increases in power may be costly. They could also increase the vulnerability of antiaircraft systems, such as surface-to-air missile systems. SAM systems—targets themselves to air-launched, antiradiation missiles—need to worry about emitting more radiation and thus becoming easier to attack.

Weapon designers could also attempt to find other methods of detecting stealthy platforms. For example, a publication put out by the Office of Naval Intelligence suggests, "Infrared search and track systems (IRST) are beginning to exploit the 8-14 micron band of the infrared spectrum. The signature of the aircraft in this band is derived from friction-induced skin heat and is hard to conceal [that could be a particular problem for planes that fly very fast for long ranges]. Although design of a reliable system in this band poses technological challenges, there is potential to detect low radar signature targets."[7] Even if that technology becomes a reality, stealthy designs may still retain some advantages in detection range, since the ranges of such systems may be limited.

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7. *Worldwide Challenges to Naval Strike Warfare*, p. 17.

Appendix B

Service Lives for Military Aircraft

How long should an aircraft operate? The term service life typically refers to the number of hours that an aircraft can be flown before the stress and strain of normal operations begin to render it unsafe to operate. From that standpoint, service life is very important to the military services and is often used as a proxy to estimate when aircraft should be removed from service, and, hence, when new aircraft are needed. Accurate, conservative estimates of aircraft service lives are therefore of great importance from both cost and operational perspectives. If aircraft do not last as long as planned, they will have to be repaired or replaced at additional cost. Moreover, the plane's operational utility is diminished if it cannot perform for the expected length of time.

How then are service lives determined? Generally, the goals for a plane's service life are established when its concept and operational requirements are being developed. Along with requirements for improvements in capability—for example, range, speed, and stealth—military planners might specify requirements for service life. They may need the plane to last 20 years and to fly 8,000 hours. Aircraft structural and materials engineers then translate those operational goals into goals for structural use.

Engineers know that over the course of a plane's service life it performs numerous maneuvers—it flies at various speeds and altitudes; carries a variety of payloads; takes off and lands numerous times; and banks, turns, and rolls frequently at various rates. All of those maneuvers place stress and strain on the aircraft's structure and cause it to deteriorate. Engineers attempt to design the aircraft structure so that under the rigors of everyday use it does not deteriorate beyond the point of usability and is as capable of flying at the end of its service life as at the beginning.

Given those challenges, aircraft engineers have a massive job in ensuring that all the structural components of an aircraft will perform as required for the length of an aircraft's service life. Aircraft resemble long chains—they are pieced together from many separate structures and are only as strong as the weakest link. Should a major structural component—such as a wing, the tail, the fuselage, or a joint or bulkhead that joins any of those structures—break during operation, the entire aircraft may be destroyed.

Because failure of any major aircraft component in flight can result in disaster, the engineers must understand how those components respond to stress and strain individually and as part of the complete aircraft. To that end, aircraft engineers use computer models as well as physical tests to gauge the ability of aircraft components to withstand the rigors of flight.

Computer models simulate how aircraft components respond when they are flexed, stretched, and twisted with various levels of force. Hence, they provide engineers with insight into structural weaknesses—for instance, where cracks are likely to form and how those cracks might grow. The models allow engineers

to predict how long a structural component can theoretically withstand the rigors of flight and thus determine if it is strong enough to satisfy design goals.

In addition to computer simulation, engineers subject to tests a complete airframe—designated as a test article in the Department of Defense's purchasing plans—to determine if it will meet design goals. Machines twist, flex, and shake the airframe to simulate the stresses that the plane will experience when flying. The test article is typically used to simulate flying twice the number of hours the plane is expected to fly when it is operational. Measurements are taken during such testing, and the results are compared with computer predictions to determine if the aircraft will perform as anticipated.

Testing and simulation allow engineers to determine a plane's capability to satisfy goals for its operating service life. Despite that validation, designers cannot predict the service lives of aircraft with certainty. A number of factors influence whether the engineers' predictions will pan out over the operational life of the new plane.

Limitations in the computer models that simulate the effect of flight is one factor that may introduce error into the engineers' estimates. Even relatively complex models of aircraft structural design do not faithfully simulate all of the factors at work when an aircraft component twists, slides, and bends. As computing technology becomes increasingly sophisticated, that issue may decrease in importance as one that throws off predictions of service life.

Perhaps more important in the long run is the cost of testing and evaluation. High costs may limit the ability of engineers to collect sufficient data to determine accurately whether all structural components are capable of meeting goals for service life. High-fidelity computer models are expensive to design and typically require large, powerful computers that are expensive to own and operate.

Thus, designers sometimes resort to less accurate models to assess the durability of components. In addition, full-scale testing for durability is a costly and time-consuming procedure. As a result, manufacturers may opt not to test all of an aircraft's structural components if they were tested on an earlier version of the plane (as was the case with F-16 Block 40 and Block 50 aircraft). Although that failure to test produces economies in the design process, each version of an aircraft may introduce important strains in the structural chain—even in components that were not ostensibly influenced in the modification process—that could shorten service life.

Another important limitation in determining whether an operational aircraft will meet goals for its service life is the ability of engineers to predict accurately how the aircraft will be used over the course of its service life. How violently will it be maneuvered? How fast will it will fly? At what altitudes? How much ordnance will it carry? How many takeoffs and landings will it perform? All of those factors affect the forces that the aircraft will be subject to over its lifetime and how much damage its components will incur. Thus, the success with which the Department of Defense predicts actual use—and the engineers' ability to test accurately for that level of use—will affect whether a plane will live up to its design specifications.

Engineers naturally attempt to eliminate inaccuracy as much as possible. They make informed predictions about aircraft use, relying on data from existing aircraft that perform the same or similar missions (though that method has problems of its own). Moreover, some design philosophies (such as those used by the Navy) provide room for error. Engineers might design an aircraft to specifications that are more rigid than they anticipate the average aircraft will require.

Any manufactured structure, no matter how finely fashioned, contains inherent flaws. Materials made of metal will contain microscopically small pockets or fissures imperceptible to the human eye. However, when subjected to the stress and strain of flight, those imperfections grow. That growth is what concerns engineers. They rely on computers to evaluate the numerous variables and equations that describe how materials respond to the forces of flight and attempt to predict how quickly those imperfections will grow into cracks that result in component fracture and failure.

Nonetheless, aircraft are dynamic systems, which is another way of saying that countless forces are at work both internally and externally when an aircraft operates. Therefore, assumptions and generalizations must be made when simulating aircraft use and the forces it and its components will encounter. Some of those assumptions will inevitably prove to be wrong.

Appendix C

Cost Estimates for Aircraft in the Administration's Plan: Joint Strike Fighter, F-22, and F/A-18E/F

The Congressional Budget Office estimates that the cost to develop and acquire the three aircraft in the Administration's tactical aviation plan would total $357 billion in 1997 constant dollars. The Joint Strike Fighter (JSF) program accounts for about 60 percent, or $219 billion, of that amount. The F-22 and the F/A-18 E/F programs make up the difference, costing about $70 billion and $67 billion, respectively. This appendix provides the basis for those estimates (see Table C-1).

Background

The Department of Defense uses several building blocks for determining or describing a weapon's cost. Chronologically, the first one addresses the costs to develop a system. The costs to develop an aircraft encompass engineering design, manufacturing ground and flyable test articles, and testing to establish that the design meets performance specifications.

Once the government decides to build the aircraft in a greater quantity, it incurs costs that the cost analysts describe with various terms. Those include:

- *Flyaway cost* is the most basic component and includes the costs of the airframe, engines, electronics, and other parts of the airplanes themselves.
- *Weapon systems cost* covers everything in flyaway cost plus equipment to maintain the aircraft (such as power carts and diagnostic computers), simulators for pilot training, and maintenance manuals.
- *Procurement costs* add to the cost of the previous two categories by including an initial complement of spare and repair parts.

When development and procurement costs are added to the expenses of constructing any special facilities such as operating base hangars and ramps or depots, the sum represents what analysts dub "acquisition costs" (see Table C-2 for a description of how those building blocks add up to the acquisition cost).

Acquisition Costs of the Joint Strike Fighter

The cost of the Joint Strike Fighter—at $219 billion—would have a greater impact on the budget for aircraft procurement than the other two programs combined. Procurement costs would total about $197 billion (or 90 percent of the acquisition cost) for 2,978 aircraft. CBO estimates that research and development would require another $21.5 billion (see Table C-3 for CBO's estimate for the JSF and the methods used to estimate major elements of the program).

Table C-1.
Summary of CBO Estimates for the Joint Strike Fighter, F-22, and F/A-18E/F (In billions of 1997 dollars)

Program	Development	Procurement	Military Construction	Total Acquisition
Joint Strike Fighter	21.5	197.3	0.2	219.0
F-22	22.8	47.3	0.2	70.3
F/A-18E/F	5.7	61.7	0	67.4
Total	50.0	306.3	0.4	356.7

SOURCE: Congressional Budget Office.

In contrast, the Administration has an estimate for development costs, but only goals for recurring flyaway costs and no estimate for other procurement costs. The Department of Defense's estimates development costs at $19.7 billion or about 9 percent lower than the CBO estimate; its cost goals for recurring flyaway costs are more than 40 percent lower on average. CBO estimates that the Air Force's version of Joint Strike Fighter would cost about $45 million each on average compared with DoD's goal of $30 million. As for the Navy and Marine Corps, CBO also does not expect that the cost goals could be met. Instead of Navy planes that cost from $34 million to $41 million each, CBO expects the unit cost to be about $57 million. The Marine Corps' aircraft would cost $50 million each instead of $33 million to $38 million, which is DoD's goal for that version.

Development Costs for the Joint Strike Fighter

At about $21.5 billion, development for the Joint Strike Fighter would represent about 10 percent of total acquisition costs. Development covers two distinct phases—concept development costing about $2.7 billion and engineering and manufacturing development at about $19 billion. CBO uses estimates from DoD for concept development, but departs from DoD estimates for the three main elements of engineering and manufacturing development that are the responsibility of a contractor—airframe, avionics, and propulsion—and costs of the program office and test ranges that the government bears directly. CBO estimated the first three parts based on statistical analyses, known as cost-estimating relationships, whereas the estimate for administration and the ranges assume that such costs would be 11 percent of the contractor's estimated costs—a rough percentage based on the experience of previous development programs for fighter aircraft.

The Institute for Defense Analyses (IDA) and the RAND Corporation performed the statistical analysis in separate studies to determine the mathematical relationships between costs and performance or physical characteristics of airframes, avionics, and engines. They used multiple regression techniques and data from more than 16 tactical fighter and attack aircraft, between 20 and 45 aircraft avionics subsystems, and 15 turbine engines. The size of the avionics sample varies depending on the subsystem—for example, fire control radar, computers, or controls and displays.

For airframe development, costs depend on the aircraft's weight, maximum speed, the amount of advanced materials in the airframe, and a measure of the program's complexity when many contractors are teamed in the development. The important variables for estimating avionics costs are system weight, level of integration, and technological maturity.[1] For the cost of engines, the variables driving costs are maximum airflow through the engine, engine thrust-to-weight ratio,

1. Level of integration refers to the maximum number of gates per chip available at the time the avionics system entered development.

Table C-2.
Components of the Cost of Acquisition for Tactical Aircraft

Cost Category	Cost Components
Flyaway Cost	Airframe and Avionics and Propulsion and Nonrecurring
Weapon Systems Cost	Flyaway and Logistics Support
Procurement Cost	Weapon Systems and Initial Spares and Repair Parts
Acquisition Cost	Procurement Cost; Research Development, Test, and Evaluation; and Military Construction

SOURCE: Congressional Budget Office.

NOTE: Nonrecurring costs are one-time costs not chargeable to each aircraft. They include items such as tooling purchases that are needed to achieve increases in production rate, ancillary equipment such as launchers and bomb racks, and engineering design costs for modifications made during production.

specific fuel consumption, and a measure of technology called time-of-arrival.[2]

The databases underlying the IDA and RAND analyses did not capture the added costs of developing stealth technology. They consist of systems developed before the advent of that technology. Clearly, incorporating stealth features into an aircraft has some cost penalty in both development and production. For example, during development, stealth requires additional design considerations, extra test articles and testing, unique applications of materials in the manufacturing of test articles, and greater security.

Similarly, during production, stealth still requires unique applications of materials in the aircraft, continued testing of each aircraft off the production line, and greater security in certain areas of the production facility. Quantifying that cost penalty has been difficult, however, because no research or studies have been published to shed light on this question. Informal information from industry indicates the extra cost may be about 10 percent. But CBO believes the figure may actually be higher given recent cost experience on programs like the B-2, F-117, the A-12, and the ongoing F-22. CBO chose to double the 10 percent factor in production and increase it by half again to 30 percent in development. Development receives a higher factor because the efforts to design the stealth aircraft appear greater than those needed to build the aircraft repeatedly in production.

Procurement Cost of the Joint Strike Fighter

CBO estimates that procurement costs of the Joint Strike Fighter would total about $197 billion (in 1997 dollars). CBO estimated five elements of procurement cost—airframe, avionics, propulsion, nonrecurring, and logistics support and initial spare parts. Airframe and avionics account for over half of procurement costs and were estimated using a second set of cost-estimating relationships that the Institute for Defense Analyses and RAND computed. CBO bases its estimate for propulsion costs on similar costs for the F-22 and the same sort of variables used in the estimates for airframe and avionics costs. The estimate for nonrecurring costs represents a fixed percentage of airframe, avionics, and propulsion costs combined. Costs for logistics support and initial spares represent a fixed percentage of recurring flyaway costs.

Airframe. CBO's estimate of $65 billion for airframe production costs draws on an IDA analysis of how such costs vary as a function of the airframe's weight, the percentage of advanced material used in manufacturing the airframe, and structural efficiency. The Institute for Defense Analyses derived those cost-estimating relationships based on a statistical analysis of airframe cost and technical performance data on 17 tactical fighter and attack aircraft, including the F-18, F-16, and F-15 aircraft. Because the cost-estimating relationship addresses the cost of the 100th airframe off of the production line, the Congressional Budget Office estimated a schedule of costs for 2,978 aircraft based on the estimate of the cost-estimating relationship and on a learning curve—a pattern of declining costs as a production run lengthens—that also accounts for the commonality between the three versions or models of the Joint Strike

2. This method was first used by Alexander and Nelson at RAND and was later used in RAND's engine cost-estimating models. See A.J. Alexander and J.R. Nelson, *Measuring Technological Change: Aircraft Turbine Engines*, R-1017-ARPA/PR, (Santa Monica: RAND Corporation, April 1972).

Table C-3.
CBO Cost Estimate for the Joint Strike Fighter (In billions of 1997 dollars)

Cost Component	Estimate	Primary Basis of Estimate
Development Cost	21.5	Institute for Defense Analyses and RAND Cost Equations
Procurement Cost		
Airframe	64.6	Cost Equation of the Institute for Defense Analyses
Avionics	52.5	RAND Cost Equation
Propulsion	17.4	F119 Costs Adjusted Based on IDA Equation
Nonrecurring	11.2	Percentage of Other Flyaway Costs
Subtotal, Flyaway	145.7	
Support and initial spares	51.6	Percentage of Recurring Flyaway Costs
Total, Procurement	197.3	
Military Construction	0.2	Costs for F-22, F-18, and AV-8B
Acquisition Cost of Joint Strike Fighter	219.0	

SOURCE: Congressional Budget Office.

Fighter. As with development costs, CBO raised the estimate—by 20 percent in this case—to capture the cost of stealth technology.

Avionics. CBO estimated the $53 billion production costs of JSF avionics (for example, radar, controls, and displays) using cost-estimating relationships developed by RAND. Using a database of between 20 to 45 avionics systems depending on the subsystem, RAND found that production costs for avionics depend on system weight, level of integration, and technological maturity. Like the cost-estimating relationships for the airframe, the cost-estimating relationships for avionics address the cost of the 100th system off of the production line. CBO estimated a schedule of avionics costs for 2,978 aircraft based on the estimates of the cost-estimating relationship and learning curves for avionics. CBO did not increase those estimates for "stealth" because the cost impact in production is minimal for most avionics systems.

Propulsion. CBO estimates that the costs of production of the Joint Strike Fighter engines and the special propulsion elements associated with the short takeoff and vertical landing capabilities of the model sought by the Marine Corps would be $17 billion. That estimate relies on similar costs for the F-22 engine and an equation that the Institute for Defense Analyses developed.

CBO used the costs of the F-22 engine, designated the F119, for a direct analogy because all teams of contractors for the Joint Strike Fighter have announced plans to use the F119 engine or a version of it. CBO estimated a schedule of propulsion costs for 2,978 aircraft based on the F119 engine costs, the equation of the Institute for Defense Analyses, and a learning curve for engines. CBO did not increase those estimates for the stealth factor because the effect on costs is minimal.

Nonrecurring.[3] CBO estimated the JSF nonrecurring flyaway costs (about $11 billion) as a percentage of recurring flyaway cost. On average, nonrecurring costs amount to about 8 percent of the recurring flyaway cost for this program based on separate percentages for each service for nonrecurring costs that CBO computed from the cost breakdowns provided in DoD's Selected Acquisition Reports (SARs) for various models of F-16,

3. Nonrecurring costs are one-time costs not chargeable to each aircraft. They include items such as tooling purchases that are needed to achieve increases in production rate, ancillary equipment such as launchers and bomb racks, and engineering design costs for modifications made during production.

Table C-4.
CBO Cost Estimate for the F-22 (In billions of 1997 dollars)

Cost Component	Estimate	Primary Basis of Estimate
Development Cost	22.8	Air Force Estimate
Procurement Cost		
Airframe	19.6	Cost Equation of the Institute for Defense Analyses
Avionics	12.6	RAND Cost Equation
Propulsion	5.0	F119 Costs
Nonrecurring	0.3	Percentage of Other Flyaway Costs
Subtotal, Flyaway	37.5	
Support and initial spares	9.8	F-15 Costs
Total, Procurement	47.3	
Military Construction	0.2	Air Force Estimate
Acquisition Cost of F-22	70.3	

SOURCE: Congressional Budget Office.

F-18, and AV-8B aircraft.[4] The Joint Strike Fighter is due to replace two of those three aircraft. The third, the F/A-18, is the most recent aircraft in the Navy's inventory and provides the best analogy to the JSF from a Naval perspective, and could also be replaced by the JSF in the long term.

Logistics Support and Initial Spares and Repair Parts. CBO also estimated the cost of logistics support and initial spares and repair parts as a percentage of recurring flyaway cost. On average, the costs of logistics support and initial spares amount to about 36 percent of the recurring flyaway cost for this program based on CBO's analysis of DoD's Selected Acquisition Reports for various models of the F-16, F-18, and AV-8B.

4. The Congress requires that Selected Acquisition Reports (SARs) be submitted annually on most major weapons. SARs contain information on program progress, technical capabilities, contract progress, and overall cost.

Acquisition Costs of the F-22 Fighter

CBO estimates that F-22 costs would total $70 billion (see Table C-4). Development costs for the F-22 would total about $22.8 billion, of which approximately $15.7 billion has already been spent. CBO's estimate for the remaining $7 billion covers the 1997-2002 period and is taken with minor adjustment from the Selected Acquisition Report (dated December 31, 1995) for this system. Procurement costs for 438 aircraft would total about $47 billion or nearly 70 percent of the CBO's estimate of F-22 acquisition costs. CBO's procurement cost estimate is about 18 percent higher than the Administration's estimate—about $40 billion.

As with the Joint Strike Fighter, CBO's estimate for F-22 procurement has five major elements—airframe, avionics, propulsion, nonrecurring costs, and logistics support and initial spares. The estimate of each element is based on the same methods as in CBO's estimate of the Joint Strike Fighter as follows:

- Airframe costs (about $20 billion) were estimated using the Institute for Defense Analyses' equation

showing production cost as a function of the airframe's weight, the amount of advanced materials in the airframe, and the structural efficiency of the airframe; an adjustment for the costs of stealth technology; and the learning curve implicit in the SAR for the F-22.

- The cost estimate for avionics (about $13 billion) employs the equation developed by RAND that predicts costs as a function of weight, level of integration, and technological maturity.

- Propulsion costs ($5 billion) were estimated based on cost data provided by the F119's manufacturer and the learning curve implicit in the Selected Acquisition Report for the F-22.

- Nonrecurring costs ($0.3 billion) represent a fixed percentage of recurring flyaway cost based on the cost breakdown provided in the most recent Selected Acquisition Report for the F-15, in part, because the F-22 would replace that aircraft.

- Logistics Support and Initial Spares (about $10 billion) were estimated as a percentage—26 percent—of recurring flyaway cost based on like costs of the F-15.

Acquisition Costs of the F/A-18E/F

CBO estimates that acquisition costs for the F/A-18EF total about $67 billion (see Table C-5). CBO's estimate of development costs is the same as reported by the Navy in the Selected Acquisition Report of a year ago; about $5 billion of nearly $6 billion has already been expended. Procurement of 1,000 aircraft accounts for about $62 billion or 92 percent of the cost estimate. Unlike the estimates for the Joint Strike Fighter and the F-22, CBO's estimate of procurement costs is nearly the same as the Administration's estimate—only about 1 percent higher.

This aircraft presents a less complicated challenge than the Joint Strike Fighter or the F-22 because much more is known about the FA-18's costs. The Navy and Marine Corps have already bought over 1,000 earlier models of this aircraft, and drawing on the cost history of those purchases provides a rough first cut at the cost of the E and F models. Much of the FA-18E/F avionics is the same as that on the C and D models; and the engine is a derivative of the existing C and D engine, the F404. The later model's airframe, however, is much

Table C-5.
CBO Cost Estimate for the FA-18E/F (In billions of 1997 dollars)

Cost Component	Estimate	Primary Basis of Estimate
Development Cost	5.7	Navy Estimate
Procurement Cost		
Recurring Flyaway	41.7	Previous Models Adjusted for Weight Differences
Nonrecurring	6.6	Percentage of Recurring Flyaway Costs Based on Earlier Models
Subtotal, Flyaway	48.3	
Support and initial spares	13.3	Percentage of Recurring Flyaway Based on Earlier Models
Total, Procurement	61.7	
Military Construction	0	Facilities Already Exist for Earlier Models
Acquisition Cost of FA-18E/F	67.4	

SOURCE: Congressional Budget Office.

different—some would say the E and F are practically new aircraft instead of a variation on an existing aircraft. Consequently, CBO approached the estimates of FA-18E/F costs at a higher level of aggregation than the estimates for the Joint Strike Fighter and the F-22.

CBO estimated three elements of procurement costs—recurring flyaway, nonrecurring flyaway, and initial support and spares. The estimate for recurring flyaway costs ($41.7 billion) assumes that those costs would be the same as the earlier models, adjusted for the E/F's extra weight. Specifically, the estimate assumes that the program would cost the same as the first 1,000 earlier models except that the heavier E/F model would cost 36 percent more based on the ratio of its weight to the weight of earlier models. Recurring flyaway accounts for 68 percent of the F/A-18E/F procurement estimate.

CBO expects that nonrecurring flyaway cost and logistics support and initial spares for E and F models would be the same percentage of recurring flyaway costs as they were for earlier models. Based on the cost breakdowns provided in the F/A-18 Selected Acquisition Report, nonrecurring flyaway cost would total about $7 billion—about 16 percent of recurring flyaway costs. For logistics support and initial spares, the cost would represent 32 percent of recurring flyaway cost or about $13 billion.

List of Abbreviations

AMRAAM	Advanced Medium-Range Air-to-Air Missile
ASTOVL	advanced short takeoff vertical landing
ASRAAM	Advanced Short-Range Air-to-Air Missile
ATF	Advanced Tactical Fighter
AWACS	airborne warning and control system
C^3I	command, control, communication, and intelligence
DoD	Department of Defense
EIA	Electronics Industry Association
EMD	engineering and manufacturing development
FMRAAM	Future Medium-Range Air-to-Air Missile
FYDP	Future Years Defense Program
GAO	General Accounting Office
GDP	gross domestic product
HARM	High-Speed Anti-Radar Missile
IDA	Institute for Defense Analyses
IRST	infrared search and track
JAST	Joint Advanced Strike Technology
JDAM	Joint Direct Attack Munition
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Attack Radar System
MICA	*Missile d'Interception et de Combat Aérien*
MRF	Multirole Fighter
MSIP	multistaged improvement program
NATF	Navalized Advanced Tactical Fighter
ONI	Office of Naval Intelligence
RCS	radar cross section
RDT&E	research, development, test, and evaluation
RIA	Replacement Interdiction Aircraft
SAM	surface-to-air missile
SAR	Selected Acquisition Report
SSF	STOVL Strike Fighter
STOVL	short takeoff vertical landing
TACAIR	tactical air
UAV	unmanned aerial vehicle